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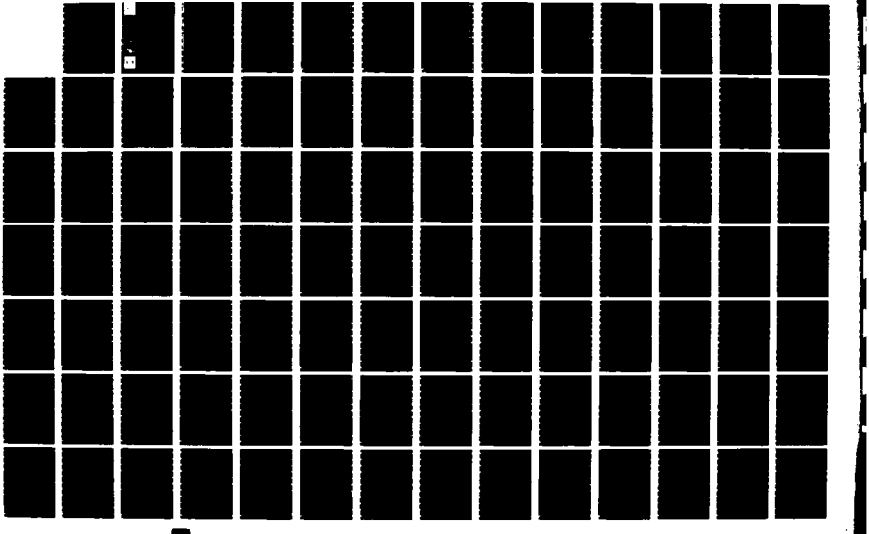

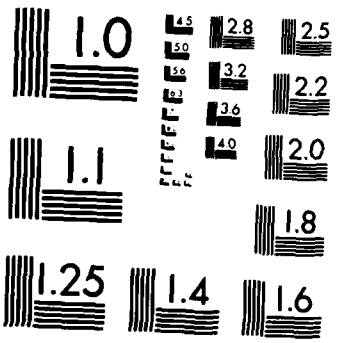

US Army Corps of Engineers

ENVIRONMENTAL AND WATER QUALITY
OPERATIONAL STUDIES

TECHNICAL REPORT E-86-10

EFFECTS OF FLOW ALTERATIONS ON TROUT, ANGLING, AND RECREATION IN THE CHATTAHOOCHEE RIVER BETWEEN BUFORD DAM AND PEACHTREE CREEK

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This report presents a case-history application of the Physical Habitat Simulation (PHABSIM) system, developed by the US Fish and Wildlife Service. The application was intended to aid in resolving the instream flow needs conflicts among water supply, trout habitat, and recreation which would result from operation of a reregulation dam downstream of Buford Dam, Chattahoochee River, Georgia. This study documents how potential downstream conflicts

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over project operation to meet fishery, recreational, and other project purposes can be approached, formalized, and resolved from both an institutional and technical standpoint. Results of the study document that multiple downstream uses of the releases from the reregulation dam can be accommodated with relatively minor changes in project operation.

PREFACE

This report was prepared cooperatively by the Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss.; the Instream Flow Group, Western Energy and Land Use Team, US Fish and Wildlife Service (FWS), Fort Collins, Colo.; and the Office of Ecological Services, FWS, Panama City, Fla. This study was sponsored jointly by the Environmental and Water Quality Operational Studies (EWQOS) Program, Task IIB, "Guidelines for Determining Reservoir Releases to Meet Environmental Quality Objectives," and the US Army Engineer District (USAED), Savannah. The EWQOS Program is sponsored by the Office, Chief of Engineers (OCE), US Army, and is assigned to the WES under the management of the EL. The OCE Technical Monitors were Mr. Earl E. Eiker, Dr. John Bushman, and Mr. James L. Gottesman. The USAED, Savannah, Coordinator was Mr. Tom Yourk.

This report was written by Dr. John M. Nestler and Ms. Janet Fritschen of the EL; Dr. Robert T. Milhous of the Western Energy and Land Use Team, FWS; and Mr. Jay Troxel of the Office of Ecological Services, FWS, Panama City, Fla. Ms. L. Toni Curtis performed some of the analyses in the report and generated many of the figures. The report was reviewed by Drs. Marc Zimmerman and James Martin. This report was prepared under the direct supervision of Dr. Nestler and under the general supervision of Mr. Mark S. Dortch, Chief, Water Quality Modeling Group; Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division; and Dr. John Harrison, Chief, EL. Dr. Jerome Mahloch was the Program Manager of EWQOS. The report was edited by Ms. Jessica S. Ruff of the WES Information Products Division.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
square feet	0.09290304	square metres

A-1

EFFECTS OF FLOW ALTERATIONS ON TROUT, ANGLING, AND RECREATION IN THE CHATTAHOOCHEE RIVER BETWEEN BUFORD DAM AND PEACHTREE CREEK

PART I: INTRODUCTION

1. The US Army Corps of Engineers (CE) develops and manages water resources in a manner consistent with environmental quality. That is, the CE considers and seeks to balance the developmental and environmental needs of the Nation (US Army Corps of Engineers 1983). As part of its role in the development of water resources, the CE operates reservoir projects to fulfill authorized project purposes such as flood control, water supply, navigation, and power generation. The operation of reservoir projects can cause considerable alteration in preimpoundment conditions. The storage and release of impounded water can modify flows, channel morphology, temperatures, and concentrations of dissolved gases and other water quality conditions in the tailwater, thereby altering or disturbing the downstream system.

2. Management of water resources by the CE through the operation of reservoir projects in a manner that is consistent with environmental quality can be best achieved by using methods that predict the direct consequences of project operation on downstream fish habitat, water quality, and river recreation. In this way, general and site-specific impacts associated with each design and/or operational alternative can be evaluated in the planning stages so that the least detrimental alternative can be selected.

3. This report presents the results of cooperative studies performed by the US Army Engineer Waterways Experiment Station (WES) and the US Fish and Wildlife Service (FWS) to predict the effects of reregulation of the Chattahoochee River below Buford Dam, Georgia, on downstream trout habitat and recreation potential. This case-history study demonstrates how potential downstream conflicts over project operation can be approached, formalized, and resolved using the Physical Habitat

Simulation System developed by the FWS. The results of this study are presented as a case-history analysis because of the relevance and timeliness of the study results to many similar concerns facing other US Army Engineer District offices. The final results of this study demonstrate that it is possible to factor into project operation the downstream recreation and fishery needs without jeopardizing project operation (in this case, for water supply).

Background

4. In 1974, county governments in the Atlanta vicinity realized that demands on the Chattahoochee River for water supply plus the streamflow required to maintain adequate water quality nearly equaled the minimum flow in the river. Increased demands for water supply in the following years could not be supplied under the then existing flow regime in the river. In response to the anticipated shortage of water, the Atlanta Regional Commission, a multicounty agency responsible for comprehensive regional planning in the Atlanta region, was contracted to prepare water demand projections to the year 2010 and identify alternatives for meeting projected water demands. The results of this study are published in an extensive final report, the Metropolitan Atlanta Area Water Resources Management Study (Atlanta Regional Commission 1981).

5. Many of the identified alternatives to increase future water supply for the Atlanta area would result in modifications to the present flow regime within the Chattahoochee River between Buford Dam (river mile 348.3) and its confluence with Peachtree Creek (river mile 300.5). The present preferred alternative is construction of a reregulation dam at about river mile 342. The proposed reregulation dam would release a much more constant flow than the peaking flows presently released from Buford Dam (generally, a maximum release of approximately 8,000 cfs* or a minimum release of about 550 cfs) by storing the generation releases

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

from Buford Dam for gradual release during nongeneration periods. The anticipated minimum release from the reregulation dam would be approximately 1,050 cfs (based on contractual obligations to the Southeast Power Administration to supply a minimum of 11 hr of peaking power per week from Buford Dam). The average annual release from the proposed reregulation dam into the Chattahoochee River would be approximately 2,000 cfs (based on US Geological Survey (USGS) flow records) and the median release would be approximately 1,500 cfs (value obtained from the US Army Engineer District, Savannah). The proposed reregulation dam would have sufficient storage to provide some opportunity for flow management to optimize uses other than water supply and water quality. Pump-back hydropower operation is not planned for this reregulation dam.

6. Flow modifications (and resultant water quality changes) within this reach of the Chattahoochee River to meet increased demands for water supply may have an effect on other beneficial uses of this important natural resource. In addition to supplying a significant proportion of the water supply for metropolitan Atlanta and providing for adequate water quality in the Chattahoochee River, the releases from Buford Dam also support substantial downstream fishery and recreational resources. Altered flows in the channel to meet water supply needs may have an impact on river recreation and trout habitat.

Objective

7. This report relates the potential for different types of river recreation and the quality of trout habitat to flow conditions (discharge) in the Chattahoochee River between Buford Dam and the confluence with Peachtree Creek. The investigation was limited to this section of the river because the major wastewater return that enters near Peachtree Creek is generally considered the lower boundary of both the trout fishery and recreation area. This report is designed to be used as a planning aid, both to identify the effects of flow alterations in the Chattahoochee River on recreation and fishery resources and to provide information for planners to develop management plans that allow

optimal use of this natural resource for power generation, water supply, water quality, trout fishery management, and recreation. Although the study design was targeted to the anticipated flow regime of the proposed reregulation dam, the results of this study can be applied to other alternatives as well.

8. The fish species/life stages and the angling and recreational activities targeted for investigation in this study are listed below. Selection of the items was based on site visits by the authors of this report and by consultation with representatives of agencies having a mission that includes responsibility for some aspect of management on the Chattahoochee River. The fisheries part of this report was limited to trout, based on recommendations of other agencies and the uniqueness, value, and popularity of the trout fishery.

Fish Species and Life Stages	Angling Activities	Recreation Activities
Juvenile brown trout	Wade fishing	Water contact wading
Adult brown trout	Tube fishing	Canoeing - novice
Adult rainbow trout	Nonpower boat fishing	Canoeing - midlevel
Adult brook trout	Low-power boat fishing	Rafting - novice (preferred)*
		Rafting - novice
		Rafting - midlevel
		Rafting - landing

* Based on reduced velocity and depth criteria for enhanced safety.

Site Description

Physical description

9. The reaches of river investigated in this report (see Figures 1-3) are bounded upstream by Buford Dam (river mile 348.3) and downstream by the confluence with Peachtree Creek (river mile 300.5). Several noteworthy features occur within the study reach. A major water intake is located just upstream of Peachtree Creek, and treated wastewater enters the Chattahoochee River downstream of Peachtree Creek.

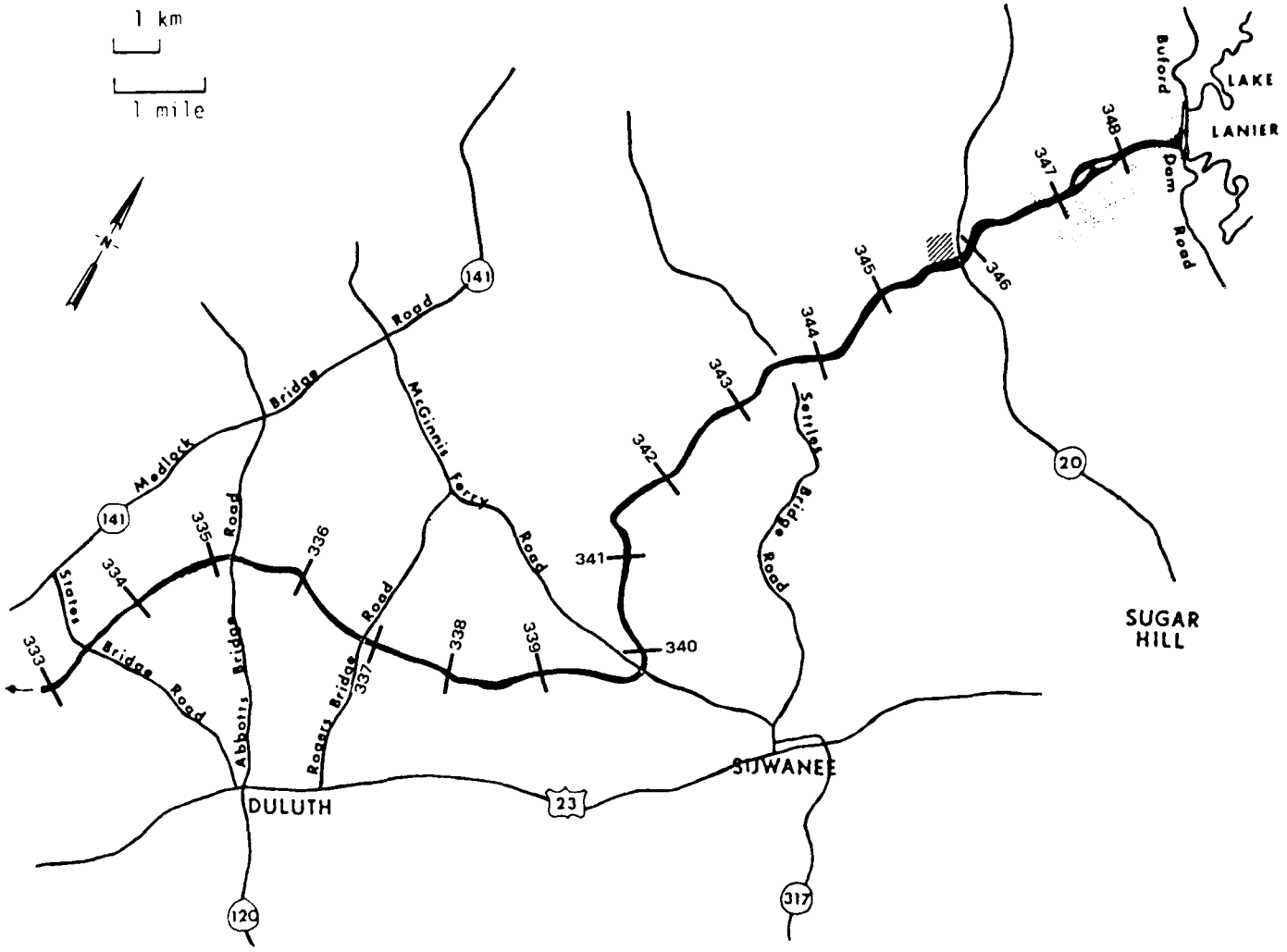


Figure 1. Location map of the Chattahoochee River from Buford Dam to below States Bridge Road, showing roads, bridges, public lands (dotted areas), and private recreational lands (cross-hatched areas) (modified from Hess 1980)

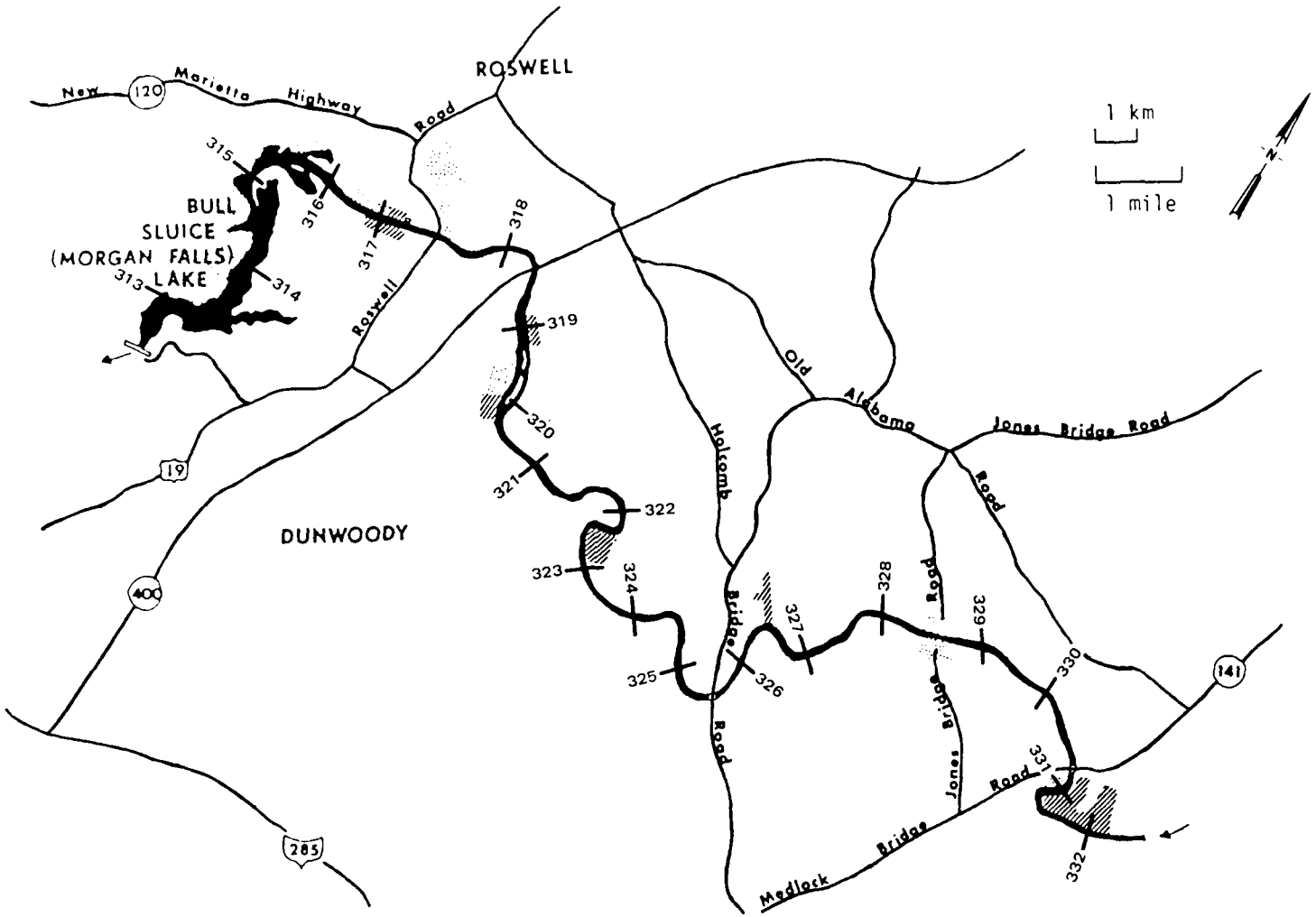


Figure 2. Location map of the Chattahoochee River from below States Bridge Road to Morgan Falls Dam, showing roads, bridges, public lands (dotted areas), and private recreational lands (cross-hatched areas) (modified from Hess 1980)

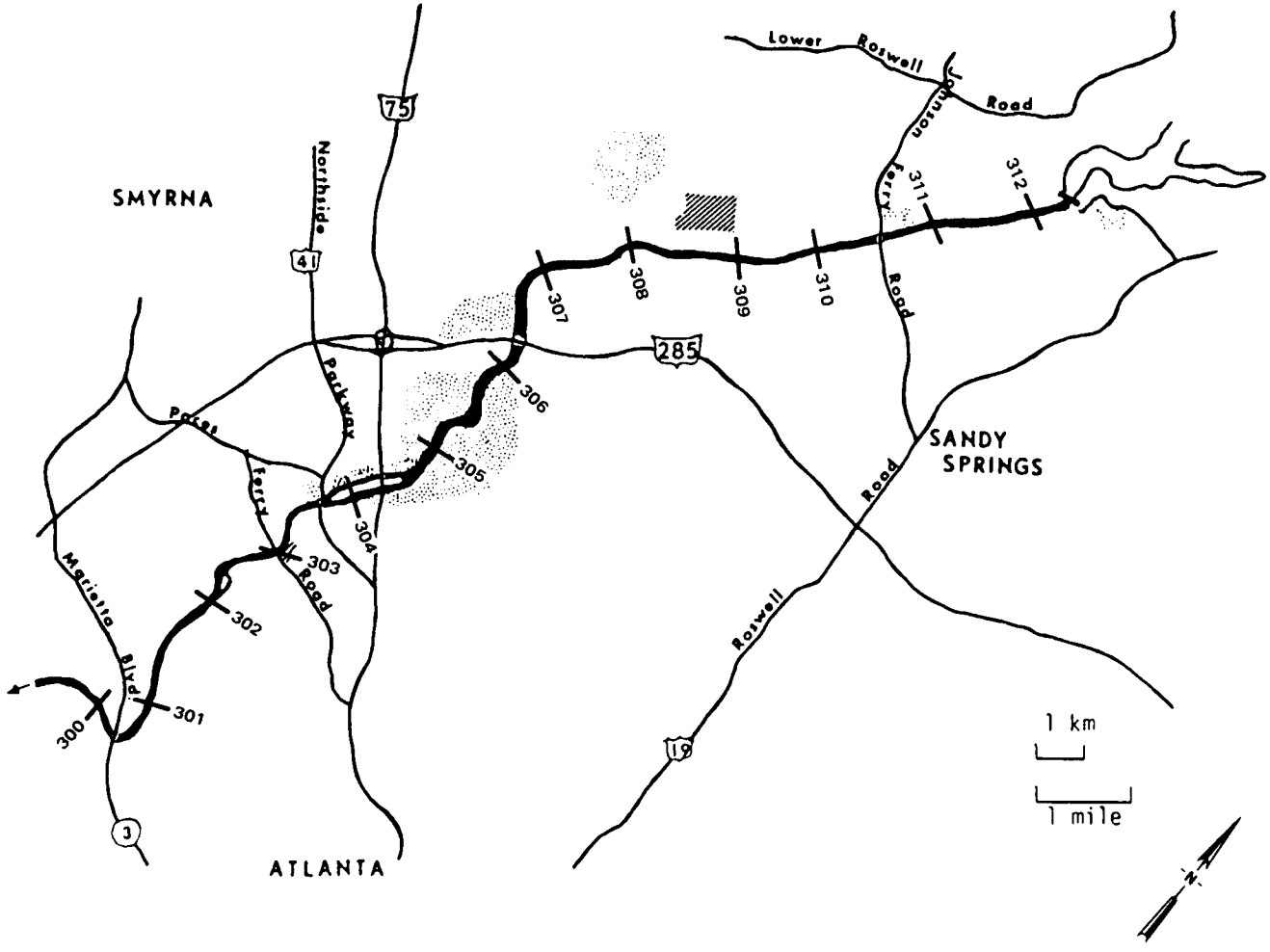


Figure 3. Location map of the Chattahoochee River from Morgan Falls Dam to Marietta Boulevard (just downstream of the confluence of the Chattahoochee River and Peachtree Creek), showing roads, bridges, public lands (dotted areas), and private recreational lands (cross-hatched areas) (modified from Hess 1980)

Included within the study length of the Chattahoochee River are several other major water intakes and Morgan Falls Dam (river mile 312.5). Morgan Falls Dam (which creates Bull Sluice Lake) is a small Georgia Power Company hydropower dam. The storage capacity of Morgan Falls Dam has been substantially reduced by siltation to the extent that the daily operation of Morgan Falls Dam is largely determined by the flows entering Bull Sluice Lake. Morgan Falls Dam is currently operated to provide a minimum release of 1,050 cfs.

10. The closing of Buford Dam in 1956 to form Lake Sydney Lanier resulted in substantial flow and water quality changes in the Chattahoochee River below the dam. Summertime releases from Buford Dam are substantially cooler than preimpoundment temperatures because the dam intakes are located in the hypolimnion (depth of approximately 69 ft below the surface) of Lake Sydney Lanier. River water temperatures usually fluctuate between 9° and 15° C, although water temperatures exceeding 20° C occur in the summer in the lower reaches. Dissolved oxygen concentrations are normally close to saturation, although low oxygen levels and poor water quality of releases occur near Buford Dam during the late summer and autumn.

11. Operation of Buford Dam to generate peaking hydropower has considerably altered the preimpoundment flow regime. Buford Dam is operated for peaking power generation for a minimum of 11 hr per week. Generally, peak releases of approximately 8,000 cfs occur during the afternoons and evenings of weekdays. Minimum releases near 550 cfs are discharged during all other time periods. On autumn weekends, increased flows may be released from the dam to improve water quality conditions at the trout hatchery located near Buford Dam.

12. Channel morphometry and substrate composition within the Chattahoochee River vary between Buford Dam (river mile 348.3) and Peachtree Creek (river mile 300.5). In general, reaches of the Chattahoochee River can be placed into one of three classifications:

a. Shoals - where the river is between 300 and 680 feet wide, relatively shallow (can be easily waded at low flow except for an occasional deep channel), stream gradient is steep (12.5 ft per mile), and the substrate is

predominantly bedrock (see Figure 4, river mile 305.7, for a representative cross section).

b. Runs - where the river is between 200 and 300 ft wide, can be waded with difficulty at low flow, the stream gradient is moderate (2 ft per mile), the substrate is composed of shifting sand, and the banks are composed of a silt and sand mixture (see Figure 4, river mile 345.8, for a representative cross section).

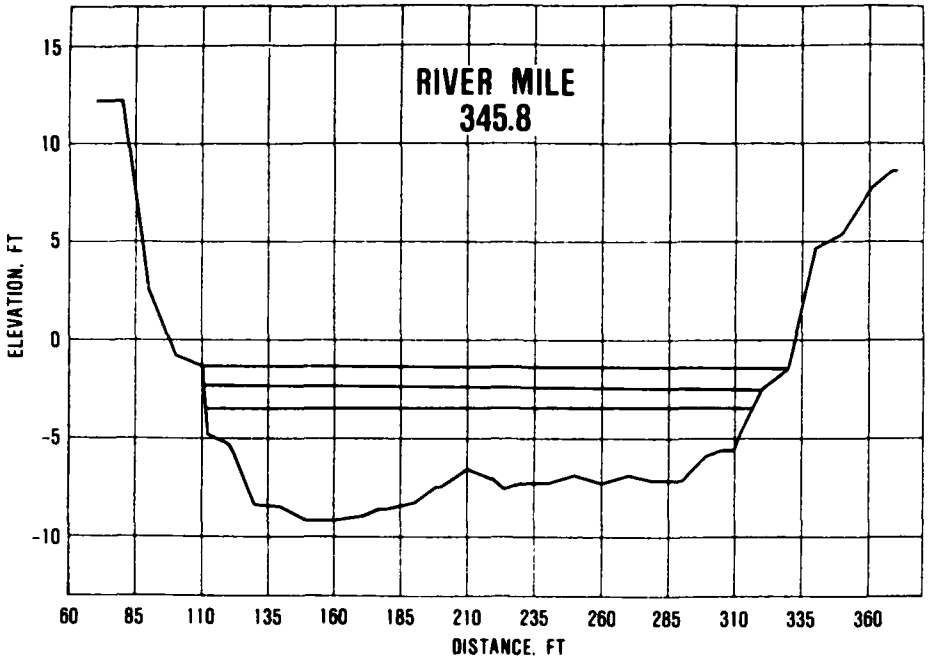
c. Pools - where the river is less than 200 ft wide, deep (cannot be waded at low flow), stream gradient is low, and the substrate is composed of silt (see Figure 4, river mile 305.4, for a representative cross section).

13. In addition to discrete types of channel morphometry, the Chattahoochee River also exhibits several general trends in flow characteristics. The change in width resulting from change in discharge over a flow range of 1,000 to 7,000 cfs is not large. Except for one location (the sand/gravel bar at Paces Mill), the change in width with discharge is less than 10 percent. Also, the change in stage resulting from a change in flow from 1,000 to 7,500 cfs decreases progressively downstream as the river widens and the gradient increases. Table 1 presents a listing of some representative cross sections to further describe the channel characteristics of the Chattahoochee River.

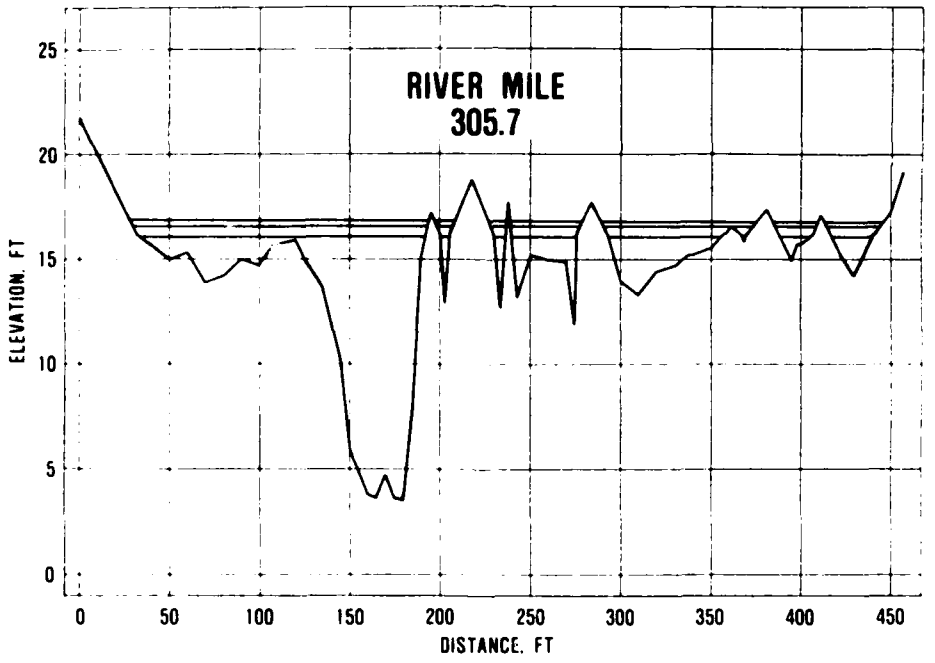
14. The results of the instream flow study are presented separately for each of the three major segments of the Chattahoochee River (also referred to as major reaches): (a) from Buford Dam to the site of the proposed reregulation dam, (b) from the site of the proposed reregulation dam to the headwaters of Bull Sluice Lake, and (c) from Morgan Falls Dam to the confluence with Peachtree Creek (Table 2). Subreaches within each major reach were identified through site inspection, consultation with local experts, and reference to existing maps and cross-section information. Note also that each major reach is bounded upstream by a hydraulic control structure. Therefore, flow conditions within each major reach can be potentially manipulated, to a limited extent, independently of the other major reaches.

Habitat and fishery description

15. The year-round availability of cool water has allowed the development of a valuable put-and-take trout fishery in this formerly

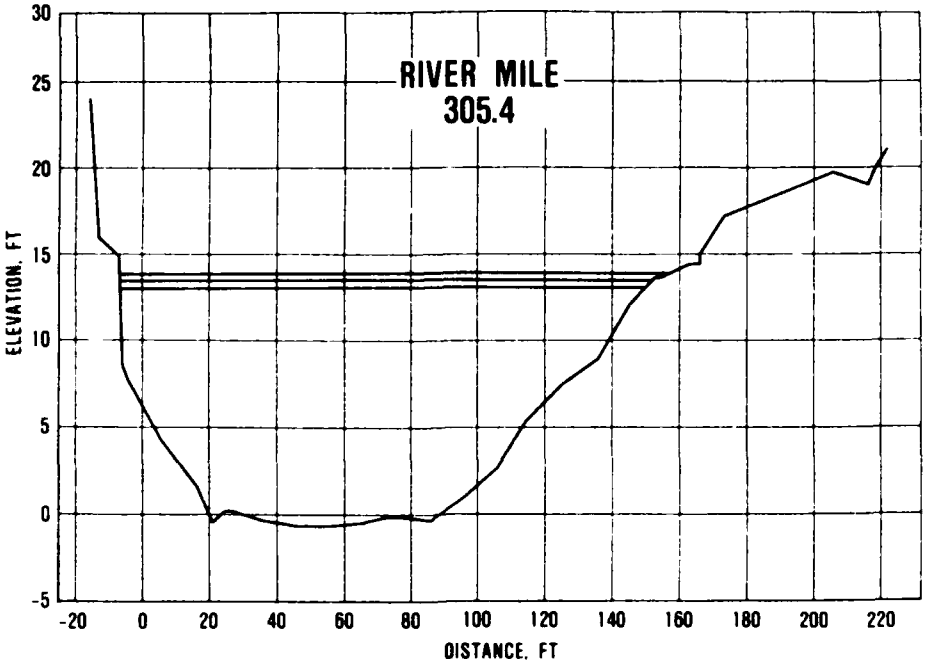


a. Run - from Devil's Race Course, river mile 345.8

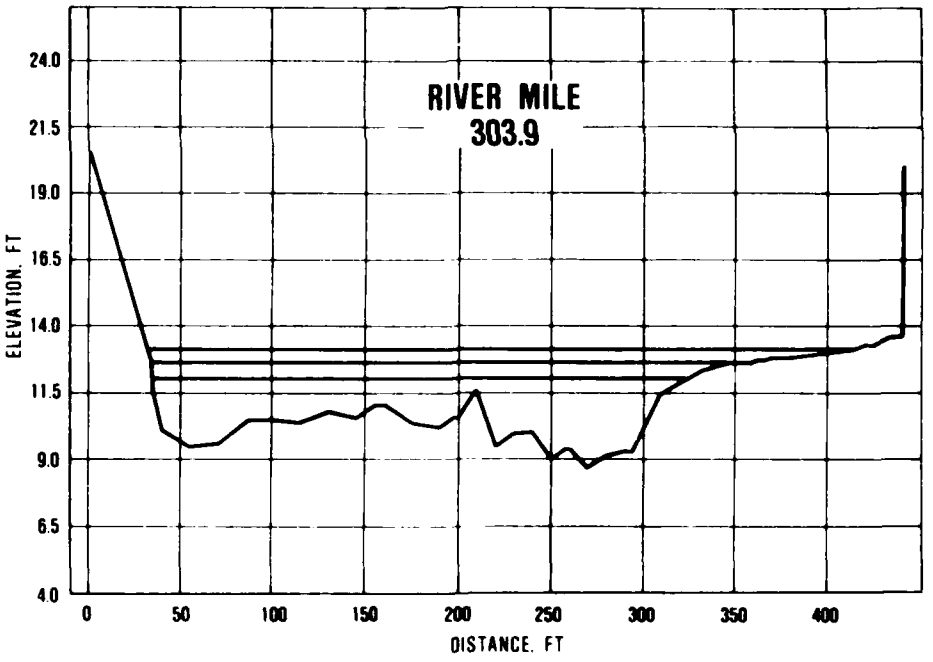


b. Shoal - near Buford Dam, river mile 305.7

Figure 4. Representative cross sections depicting different types of channel morphology of the Chattahoochee River (Continued)



c. Pool - at diving rock, river mile 305.4



d. Sand/gravel bar - at Paces Mill, river mile 303.9

Figure 4. (Concluded)

warmwater stream. In fact, the Chattahoochee River supports one of the southernmost tailwater trout fisheries in the Southeast. Harvestable-size rainbow, brook, and brown trout are stocked at numerous points in the Chattahoochee River by the Georgia Game and Fish Division. Juvenile brown trout are stocked below Morgan Falls Dam by the Georgia Game and Fish Division with the assistance of Trout Unlimited. The large yearly trout stocking totals (Table 3) illustrate the importance and value of the Chattahoochee River trout fishery. Long-term survival of stocked brown trout has produced trophy-sized fish, particularly downstream from Morgan Falls Dam.

16. The value of the different major types of channel morphology differs for each of the trout species. The shoal areas in the Chattahoochee River provide both fish-food production (aquatic macroinvertebrates) and cover for all sizes of trout. Adequate habitat for larger sized trout (200 to 350 mm) can be found in the sandy runs. The largest trout (over 350 mm) are generally found in deep pools or holes having some type of rock or timber cover.

17. Although trout are the most sought-after fish by anglers, warmwater fish also still occur within the Chattahoochee River (Table 4). Nongame fish species such as gizzard shad, carp, and various suckers dominate below Morgan Falls Dam, while trout and yellow perch are most abundant above Bull Sluice Lake, although other species are harvested in the two main shoal areas (Jones Bridge and Island Ford) above Bull Sluice Lake. The Chattahoochee River below Morgan Falls Dam and upstream of the confluence with Peachtree Creek is one of the prime trout fishing areas, probably because of ease of access, nearness to population centers of Atlanta, and availability of excellent trout habitat.

Recreation description

18. Recreational activities on the Chattahoochee River can be broadly broken into angling and nonangling activities. (For purposes of this report, the latter will be referred to as recreation.) These two categories will be discussed separately in this report.

19. Angling activities. Several major types of angling

activities occur in the Chattahoochee River, determined primarily by ease of access and channel morphology. Near boat ramps, fishing from canoes and small boats with low-power outboard engines is popular. In areas where access is more difficult, bank fishing, wade-fishing, and tube-fishing are more popular. Angling activity is most concentrated in the shoal areas of the study reaches and in areas where fish are stocked.

20. Historically, concentrated fishing activities occur at different time periods than recreational activities, in an attempt to avoid conflict with other river users. Many of the concentrated angling activities occur in the morning and evening when the other recreational users is minimal. Thus, potential conflicts between these two fundamentally different user groups are avoided.

21. Recreation description. Five public agencies provide recreational facilities or services on the Chattahoochee River between Buford Dam and the confluence with Peachtree Creek. This 48-mile length of river is managed by the National Park Service as the Chattahoochee River National Recreation Area (CRNRA). The National Park Service operates 11 park units, 5 of which provide boating access to the river. During 1983, the National Park Service reported 1,081,924 visits to their units in the CRNRA. The CE also accommodates river-related recreation at two recreation areas just downstream of Buford Dam. At these areas, the CE reported 130,126 recreation days of use in 1983. Three other parks on the river are managed by Cobb, Fulton, and Gwinnett Counties.

22. Although not all parks managed by the five public agencies provide all types of recreational facilities, at least one of the following facilities is available at each park unit: boat ramp, picnic area and shelter, nature trail, grassy field for outdoor games, and a jogging/bicycling trail. In addition to the developed areas, users gain access to the river from roads which cross or run parallel to the river and across private land bordering the river.

23. A variety of recreational activities take place on or next to the river. These include rafting, tubing, canoeing, kayaking, wading,

swimming, sunbathing, picnicking, hiking, jogging, and "relaxing." Different activities predominate on different stretches of the river (Hess 1980). The following description of recreational use of the Chattahoochee River is based on several studies (Hess 1980, Little 1982, and MacDonald and Hammitt 1979) performed over a period from 1977 to 1982. It must be noted that recreational use patterns have changed since this time period, and the following description should be viewed primarily as background information. According to Hess (1980), between Buford Dam (river mile 348.3) and Jones Bridge (approximately river mile 328), the dominant activity is sightseeing. Between Jones Bridge and Roswell Road (river mile 317), the main activities tend to be sightseeing and swimming/wading. Finally, the stretch from Roswell Road to Peachtree Creek tends to be most popular for rafting/floating and swimming/wading.

24. Most nonangling recreational activity occurs in the lower part of the river between the two National Park Service park units, at Johnsons Ferry (river mile 311) and Paces Mill (river mile 304). Of the recreational use reported by the National Park Service at all CRNRA units in 1982, 84 percent occurred in this portion of the river. Several factors contribute to the popularity of this reach of the river. This area is close to Atlanta and is bordered in some areas by major apartment complexes. Concessionaire facilities at three park units within this stretch also contribute greatly to increased use, by providing facilities to park users. The concessionaire rents rafts, a limited number of canoes and kayaks, and related supplies. In addition, the concessionaire sells food and beverages and provides a shuttle bus service to transport rafters to and from their vehicles in the three park units. Between 1 May and 30 September 1983 (excluding the month of August for which figures were unavailable), the concessionnaire rented 15,257 rafts, 368 canoes, and 35 kayaks and transported 70,764 passengers on the shuttle.

25. Social profiles of the majority of park users can be utilized to more fully describe recreational use on the Chattahoochee River. Based on the results of studies conducted by Little (1982) and MacDonald

and Hammitt (1979), users of the Chattahoochee River tend to be in their late 20's and single. They are day users who live close to the area and visit it frequently. Most come to the river with a group of friends intending to relax and socialize, and enjoy meeting other people during their visit. In both studies, a sample of users was contacted onsite, interviewed, and provided with a mailback questionnaire. All park users were included in the Little (1982) study, while only rafters and floaters were interviewed in the MacDonald and Hammitt study. Despite this difference, the results of the two studies were remarkably similar. This may be due in part to the fact that 63 percent of the Little (1982) respondents had been rafting or tubing. Demographic characteristics for both groups are provided in Table 5.

26. According to the Little (1982) study, the majority of users tend to spend 4 hr or less in the area (Table 6). In addition, most users are frequent visitors, with two-thirds having visited the river at least once a month during the summer. In the Little (1982) study, the most-cited reason for going to the river was for rafting/tubing. Other reasons given were "just to relax" and "just to be with friends." The latter two were also most often given by the users sampled in the MacDonald and Hammitt (1979) study.

27. As reflected in the reasons for visiting and length of stay, it appears that for most visitors, the trip to the river was a casual experience. In the MacDonald and Hammitt (1979) study, it was found that three-quarters of the rafters came from within 25 miles and two-thirds had been planning for the trip 2 days or less. All other activities occurring on the river, with the exception of fishing, require a less specific resource and user preparation. Therefore, it is unlikely that the travel distance and advance planning of most users would have exceeded that of rafters.

28. The Chattahoochee River differs from many other popular rafting rivers in that it is not a white-water river. This difference is reflected in the type of rafters using the river. In the MacDonald and Hammitt (1979) study, 74 percent of the rafters rated their floating skills as novice or intermediate, and very few said one of their reasons

for using the river was to develop their rafting/tubing skills and abilities. This observation was supported by representatives of the Georgia Department of Natural Resources who stated that, in general, serious canoers and kayakers visit nearby rivers (several hours driving distance) which do provide a white-water experience.

PART II: MATERIALS AND METHODS

Study Organization

29. The environmental and recreational issues addressed by this study were sufficiently broad and diverse to require a multidisciplinary, team approach. An interagency study team, the Chattahoochee River Instream Flow Study (CRIFS) team, was formed from representatives of the FWS and the CE. The members of the CRIFS team, in turn, contacted other Federal and local agencies, as required, during the course of this study both to refine the issues and to obtain information required for the study. The agencies involved in the CRIFS had an agency mission that included responsibility for the Chattahoochee River, possessed a needed expertise, or requested to participate in the study. Table 7 presents a list of the agencies involved in this study, along with a brief description of their respective contributions. Consultation with many of the agencies listed in Table 7 produced the issues (paragraph 8) that the CRIFS would address.

Methods

Background

30. After careful examination of the issues related to providing increased water supply to the metropolitan Atlanta area by modifying flows in the Chattahoochee River, the CRIFS team decided to use the Physical Habitat Simulation (PHABSIM) System developed by the Instream Flow Group, FWS, as a tool to perform an instream flow study on the Chattahoochee River. PHABSIM was selected for the following reasons:

a. It was the only method that could be applied to both the fishery and recreational aspects of this study.

b. It is generally accepted by many agencies as a defensible method for assessing fish habitat.

c. The form of the results of an instream flow study using PHABSIM are amenable to resolving potential water resources conflicts.

31. The following description of PHABSIM is for the purpose of providing the reader a general understanding of the approach used in this study. More detailed information on the application of PHABSIM can be found in Instream Flow Information Papers No. 11 (Milhous, Wegner, and Waddle 1984) and No. 12 (Bovee 1982).

32. The PHABSIM System is based on the observation that most species of fish prefer certain combinations of depth, velocity, and cover and tend to avoid other combinations of these parameters. In addition, the potential for many riverborne recreational activities can be described in terms of water depth and velocity in the channel. For example, beginning canoeists require a minimum depth of water to float their canoes and a minimum water velocity to move the canoe through the water. However, water that is too deep or currents that are too rapid may create safety hazards for beginning canoeists. Thus, the hydraulic limits for the activity of canoeing by beginners can be described by suitability criteria. If the criteria (the relative value of different depths and velocities for each species or recreational activity) are known and the hydraulic conditions within the channel can be described for different discharges, it becomes possible to determine both the quality of the habitat for each species of fish and the resource potential for different recreational activities at these different discharges.

33. As described above, an instream flow study can be broadly divided into three distinct but interconnected parts. The first part involves a description of the depths, velocities, and cover available in the river at discrete discharges. The second part of an instream flow study is the development of suitability criteria for each species of fish and recreational activity. (The following sections of this report detail how these general steps were applied to the Chattahoochee River.) The last part of an instream flow study is to combine parts one and two for each discharge of interest to derive an estimate of the value or worth of the river for each species and activity.

Flow and channel geometry description

34. Reach identification. The first step in the application of

PHABSIM to the Chattahoochee River was to divide the river into study reaches (major reaches and subreaches). Once study reaches were identified, each was described using one or more detailed cross sections (see Trihey and Wegner (1981) for further details on field techniques used in an instream flow study).

35. Study reaches of the Chattahoochee River were identified by field inspection of the river by the CRIFS team and consultation with other agencies. Table 2 presents a listing of the major reaches and subreaches of the Chattahoochee River from Buford Dam (river mile 348.3) to its confluence with Peachtree Creek (river mile 300.5). In general, three types of study reaches can be identified in an instream flow study: representative reaches, conflict reaches, and critical reaches. Representative reaches can be used to describe segments of the river in which the channel morphology, slope, and cover are relatively uniform. A short section of river is identified which is representative of the flow and cover conditions in a much longer section of river. The results obtained for the relatively short representative reach can then be extrapolated to describe a much longer section of river. Conflict reaches are segments of the river in which potentially conflicting activities, for example, angling and rafting, may occur. Critical reaches are segments of the river which are extremely important to the abundance of a species or utilization for a recreational activity.

36. Each of the subreaches identified in Table 2 was assessed to determine its importance either to fish habitat or to support recreation and was then categorized as a representative, conflict, or critical reach. Shoal areas were consistently identified as being much more important, both as habitat for fish and as sites of concentrated angling and recreational activity, than nonshoal (open-river) areas. Thus, the shoal areas were viewed by the CRIFS team as being both conflict and, to a lesser extent, critical reaches.

37. One reach was included for unique reasons and deserves special mention. The Raft Ramp reach or Paces Mill (river miles 303.75 to 303.85), consisting of one cross section, was incorporated to describe the flow and channel characteristics facing rafters attempting to land

their rafts and remove them from the river. According to the National Park Service representatives, attempts by rafters to take out at the higher discharges often result in rafters being swept downstream of the takeout point, where partly submerged stumps and logs and steep banks can make takeout difficult and dangerous.

38. The types of input data (i.e., utilization of existing cross-section data or collection of detailed field data) used in the study were determined by the classification of the different reaches. Thus, collection of detailed field data was restricted primarily to shoal areas (conflict and/or critical reaches), particularly downstream of Morgan Falls Dam. Subreaches that were considered less important were described using information previously collected by either the USGS (Faye and Cherry 1980) or the US Army Corps of Engineers (1973).

39. Field data collection methods. Channel cross-section and velocity information was collected by the USGS using standard methods of stream gaging.

40. Flow simulation. A range of techniques are available in the PHABSIM System to simulate flows in river cross sections. In general, the problem of flow simulation using the PHABSIM System can be divided into two components: simulation of cross section water surface elevations, and simulation of velocity patterns across a cross section for a given water surface elevation. The Water Surface Profile (WSP) program (see Milhous, Wegner, and Waddle (1984) for more detailed information) was applied to the Chattahoochee River for those reaches where cross-section data (existing data obtained from the USGS or CE) were available and cell velocity information was unavailable. The WSP program was calibrated to stage information obtained from gages on the Chattahoochee River. Using WSP, cell velocities were derived based on the hydraulic radius of each cell (a cell is a subsection of a river cross section). A stage-discharge relationship, developed separately for each cross section, was used to determine the water surface elevations at different discharges of interest (see Trihey and Wegner (1981) for more details) for the reaches investigated as part of the field effort for this study. The IFG4 program (see Milhous, Wegner, and Waddle 1984) was then used to

determine the velocities across the cross section given the stage-discharge relationship. In the Chattahoochee River application, the IFG4 program required a set of cell-by-cell velocity measurements for each cross section at a calibration discharge to simulate cross-sectional flow patterns.

41. Channel stability analysis. The value of the results of this study are partly determined by the stability of the channel of the Chattahoochee River. Since much of the channel is composed of sand, there was some concern by the CRIFS team that the habitat relationships developed in this report would be valid only for a short time period and, consequently, of limited value from a management standpoint. The long-term stability of the channel was tentatively evaluated by comparing cross-section data collected in 1954 and 1971, by sensitivity analysis by the Instream Flow Group of the FWS, and by field observation.

Suitability criteria curves

42. Background. The PHABSIM System requires suitability criteria curves to relate information about the physical properties in the river at a particular discharge to the suitability (or usability) of the river either as physical habitat for a fish or as a potential resource for recreation. Developing and evaluating suitability criteria curves for the species and activities listed in paragraph 8 was an integral part of the CRIFS. Suitability curves for depth, current velocity, and substrate (also referred to as "cover code" or "channel index") are presented for each species investigated in this study. For each recreational activity, suitability curves for only depth and current velocity are included. The suitability curves were broken into three major categories--trout curves, angling curves, and recreation curves--based on the methods used in their development.

43. Trout suitability criteria. The criteria for trout were based initially on information available in Instream Flow Information Paper No. 4 (Bovee 1978), published by the Instream Flow Group of the FWS. However, it was the consensus of the CRIFS team that these curves were unsuitable for use on the Chattahoochee River without modification. The curves in Bovee (1978) were based on trout behavior in

streams in the Western States. Their use, without modification, on a highly managed, upper piedmont, put-and-take trout fishery downstream from a peaking hydropower project in the Southeast would be problematic, at best.

44. The suitability criteria were modified to make them more applicable to the Chattahoochee River through consultation with two recognized experts on this trout fishery, Mr. Tim Hess and Mr. Chris Martin of the Georgia Game and Fish Division. They were able to suggest a number of modifications to the depth and velocity suitability curves taken from Bovee (1978) to make them applicable to the Chattahoochee River trout fishery.

45. The suitability criteria for substrate provided in Bovee (1978) were not used in this study. New suitability curves (Table 8) for substrate were developed following the recommendations of the Instream Flow Group to design a channel index for each study (Bovee 1982). The channel index designed for the Chattahoochee River can probably be used, with caution, for other piedmont streams but should not be used for streams outside the piedmont. All of the revised curves for trout life stages are included in Appendix A.

46. Recreation and angling suitability criteria. All of the recreation and angling activities investigated in this report, except "hanging-out," are related to physical conditions in the river that could be assessed using PHABSIM. Hanging-out refers to the use of rocks for sunbathing, social gathering, and observing other recreationists. The availability of hanging-out space at different discharges was assessed using aerial photographs taken at staged flows of 1,000 and 1,500 cfs. These flows were selected because they bracket the current minimum flow in the river and the anticipated release from the proposed reregulation dam. The selected flows were released from Morgan Falls by Georgia Power on 3 June 1984 and 15 July 1984 (both Sundays). The Georgia National Guard conducted the aerial photography of the major reach below Morgan Falls at about 1400 hr EDT.

47. Criteria curves for the other recreational and angling activities (Table 9) were initially obtained from Hyra (1978), except for the

raft-landing and tube-fishing curves, and were evaluated by the CRIFS team for application to the Chattahoochee River. The study team decided that some of the curves could be used directly from Hyra (1978) whereas others would require modification before they could be used for the Chattahoochee River. The criteria for nonpower boat fishing and low-power boat fishing were obtained directly from Hyra (1978).

48. As was done for the trout suitability criteria, some of the recreation and angling criteria were modified by the CRIFS to more accurately represent the type of activities and level of use actually occurring on the Chattahoochee River. Modification of these curves and creation of new curves were performed in consultation with a panel of experts composed of representatives of the Georgia Department of Natural Resources and the National Park Service. The curves for fishing by wading were modified from the curve in Hyra (1978) by direct field measurement of the flow conditions in which a group of individuals wearing rubber waders could easily move through the water. Depths and current velocities uncomfortable to waders were recorded and served as points of zero suitability. The curve for tubing represents the floating phase of the total tube-fishing activity (which includes both floating and wading).

49. The curves for rafting and canoeing were first modified from those given in Hyra (1978) based on information obtained in a floating guide to Western rivers (Schwind 1974). To further refine these curves, a site visit was made to Devils Race Course Shoals and Jones Bridge Shoals by members of the CRIFS team and the panel of experts on river recreation. During this site visit, depths and velocities in different areas of the shoals were measured to provide the group with several reference points. These data were then used by the study team, with the consultation and assistance of the panel of experts, to modify the initial rafting and canoeing curves obtained from Hyra (1978) for use on the Chattahoochee River. The angling and recreation suitability criteria are provided as Appendixes B and C, respectively.

50. Travel time and average velocity determination. Discussions held with representatives of the National Park Service indicated that

the travel time of rafters and canoeists at different discharges may be an important consideration in determining the quality, and certainly the duration, of the recreation experience. The travel time down the river is at least partly related to the average velocities in the river, even though the actual travel time is also dependent upon where in the channel the rafter or canoeist is located. Thus, a knowledge of the average velocities for specific discharges in the channel can provide an estimate of relative differences in travel time to be encountered by a rafter or canoeist. Average velocity determinations for each reach were provided by the Instream Flow Group of the FWS.

51. Mean cross-sectional velocity was obtained by dividing discharge by cross-sectional area at each transect. Mean reach velocity was estimated by taking the mean of the cross-sectional velocities, where each cross-sectional velocity was weighted by the length of channel represented.

PART III: RESULTS

Evaluation of Channel Change

52. The long-term management value of any study which documents the flow requirements for fish, angling, and recreation is partly determined by the stability of the river channel. If the river channel changes considerably over time, the study results are of little long-term value. Several processes are presently occurring in the channel of the Chattahoochee River which could affect the results of this study. Field observation indicates that channel widening due to bank scour has occurred in the past and is probably continuing. The widening may be important for some considerations, but sensitivity analysis performed by the Instream Flow Group indicates that the amount of bank scour will not likely have an appreciable effect on the habitat or recreation space versus streamflow relationships generated by this study. Evaluation of historical data indicated that bed material has been scoured out below Buford Dam to about river mile 346. However, the continued degradation of the channel is unlikely since the river channel has reached bedrock at the State Road 20 Bridge (Figure 1).

53. Again, the results of this study should not be substantially affected by changes in the channel of the Chattahoochee River. Bank sloughing occurs between Bowmans Island and about river mile 339. The effects of modified flows within the Chattahoochee River on bank sloughing are unknown. However, since this reach of river is of relatively less value (compared with the other sections of the river) for recreation or for trout habitat, even moderate increases in bank sloughing will not have a substantial effect on overall trout habitat or recreation in the river. Bank sloughing could potentially occur between Bowmans Island Shoals and the site of the reregulation dam if a reregulation dam is constructed. Estimates of the amount of channel change to be expected in this section by flow modifications are further confounded by the activities of commercial sand dredgers.

Interpretation of Results

54. The results of PHABSIM analyses are ordinarily presented in terms of "weighted usable area" (WUA) per some length of river. The WUA is defined as the surface area of river (square feet in this report) available for either a target fish species or recreational activity. The term "weighted" refers to the way in which the area calculation is made. Each cross section is laterally discretized into a series of cells for which depth and water velocity (at a given velocity) and substrate may be determined. Each cell represents a portion of the total area of the cross section equal to its width times the length of river over which the cross section applies. Thus, if a cell top width is 3 ft and the cross section represents a length of river 100 ft long, then the cell represents flow conditions in 300 (3 × 100) sq ft of river.

55. The surface area of river is then modified using information from the suitability curves. For example, if the water velocity in the cell falls within the optimum range (has a suitabiity value of 1.0) for velocity from the suitability curve, and the channel index for the cell likewise has a value of 1 but depth conditions in the cell have a suitability of 0.5, a weighting factor of 0.5 (obtained by multiplying the individual suitabilities: 1.0 × 1.0 × 0.5 = 0.5) is assigned to the surface area represented by the cell. For this example, a total of 150 sq ft (300 sq ft × 0.5 weighting factor) of WUA would occur in the river represented by the one cell.

56. This procedure is repeated for each cell in a cross section to determine the WUA for a target species or activity (at a constant discharge) for the length of river represented by that cross section. The WUA available in a long river reach at a given discharge can be described by summing the WUA's obtained for separate cross sections. For further information concerning the relationship between river surface area and suitability calculations, the reader is referred to Bovee (1982).

57. For the sake of brevity, the results of this study are

presented as major reach summaries, although results could also be presented as totals for each subreach within the major reaches. The summary figures present the mean WUA for a length of river 1,000 ft long for each of the three major reaches identified in the report (Buford Dam to the site of the proposed reregulation dam, the site of the proposed reregulation dam to the headwaters of Bull Sluice Lake, and Morgan Falls Dam to the confluence with Peachtree Creek). The figures were obtained by summing all of the WUA's for each subreach and then dividing through by the total length of the major reach and multiplying by 1,000 ft. This type of data presentation allows for direct comparison between reaches of different lengths. The total WUA for each major reach can be obtained by multiplying the mean values by the total length of the major reach and dividing by 1,000 ft.

58. The results could also be presented by subreach to allow assessment of different flows at specific points along the river. For example, because of channel morphology, habitat for a life stage of trout or potential for a particular recreational activity may be optimum along a subreach of river at a particular discharge, whereas it may be marginal for the reach considered as a whole. In some instances, the information presented in this fashion can be a useful management tool.

Trout Habitat

General results

59. The general results obtained for trout of all life stages for the major reaches were similar (Figures 5-7). In all cases, habitat for each species peaked at a discharge under 2,000 cfs and then declined to a minimum at the highest simulated discharge of 12,000 cfs.

60. The four species life stages investigated in this report could be placed into two groups. The WUA-discharge relationships for adult rainbow trout and adult brown trout were generally similar. The WUA-discharge curve of both peaked at approximately 1,500 cfs and then declined to a minimum at 12,000 cfs. For brook trout and juvenile brown trout, the WUA-discharge relationships peaked at or under 1,000 cfs and

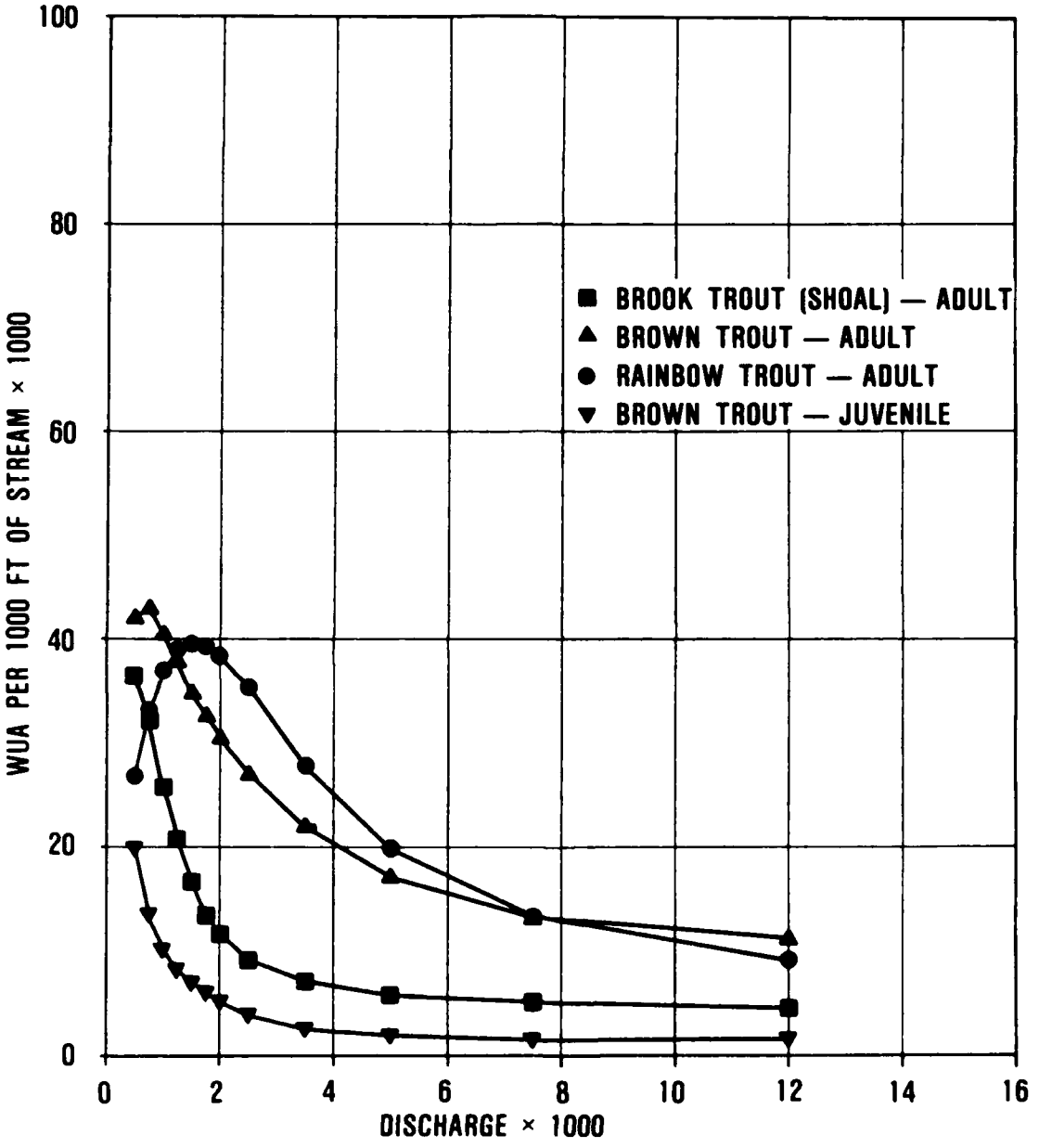


Figure 5. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for trout life stages for the major reach from Buford Dam to the site of the proposed reregulation dam

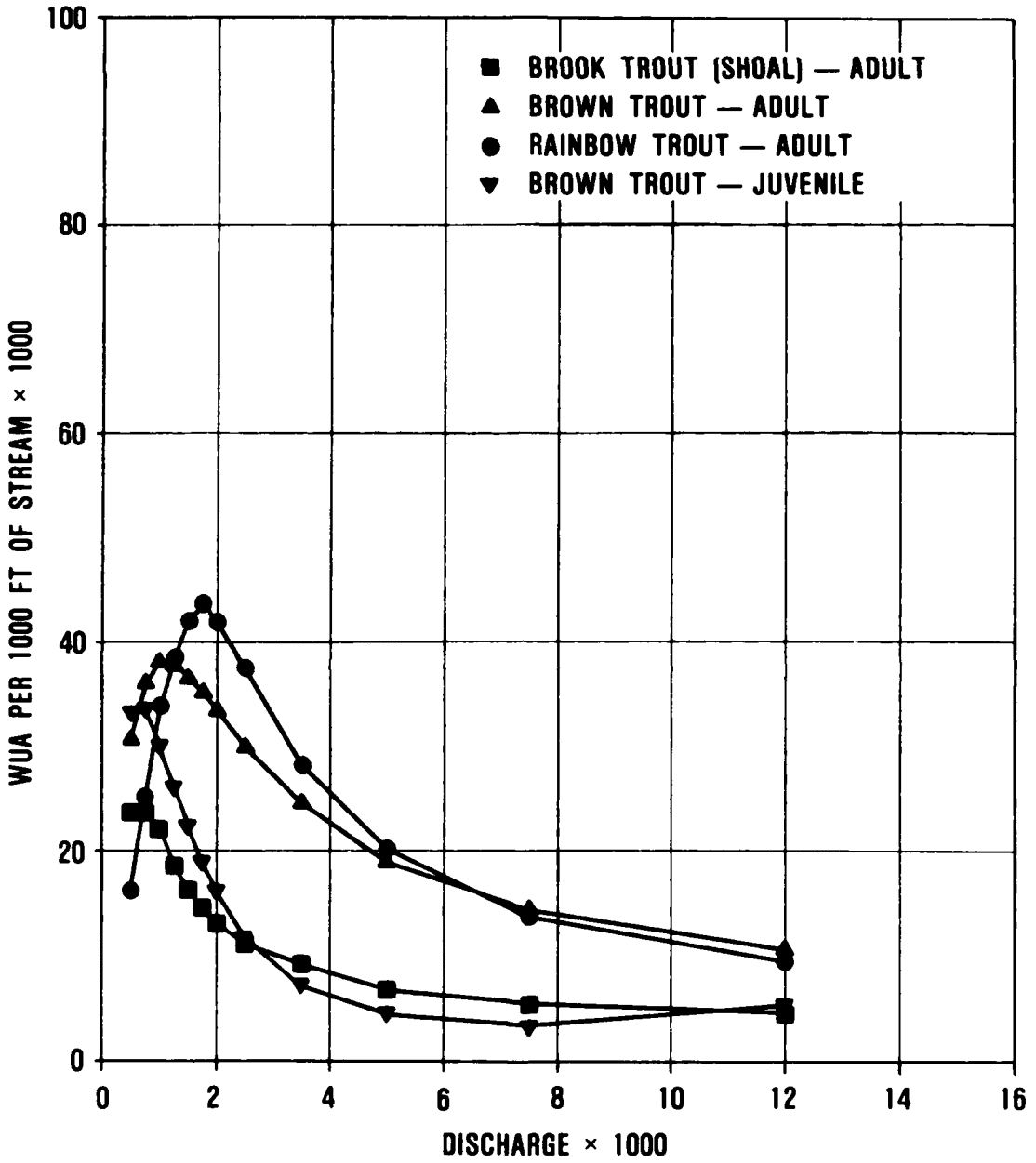


Figure 6. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for trout life stages for the major reach from the site of the proposed reregulation dam to the headwaters of Bull Sluice Lake

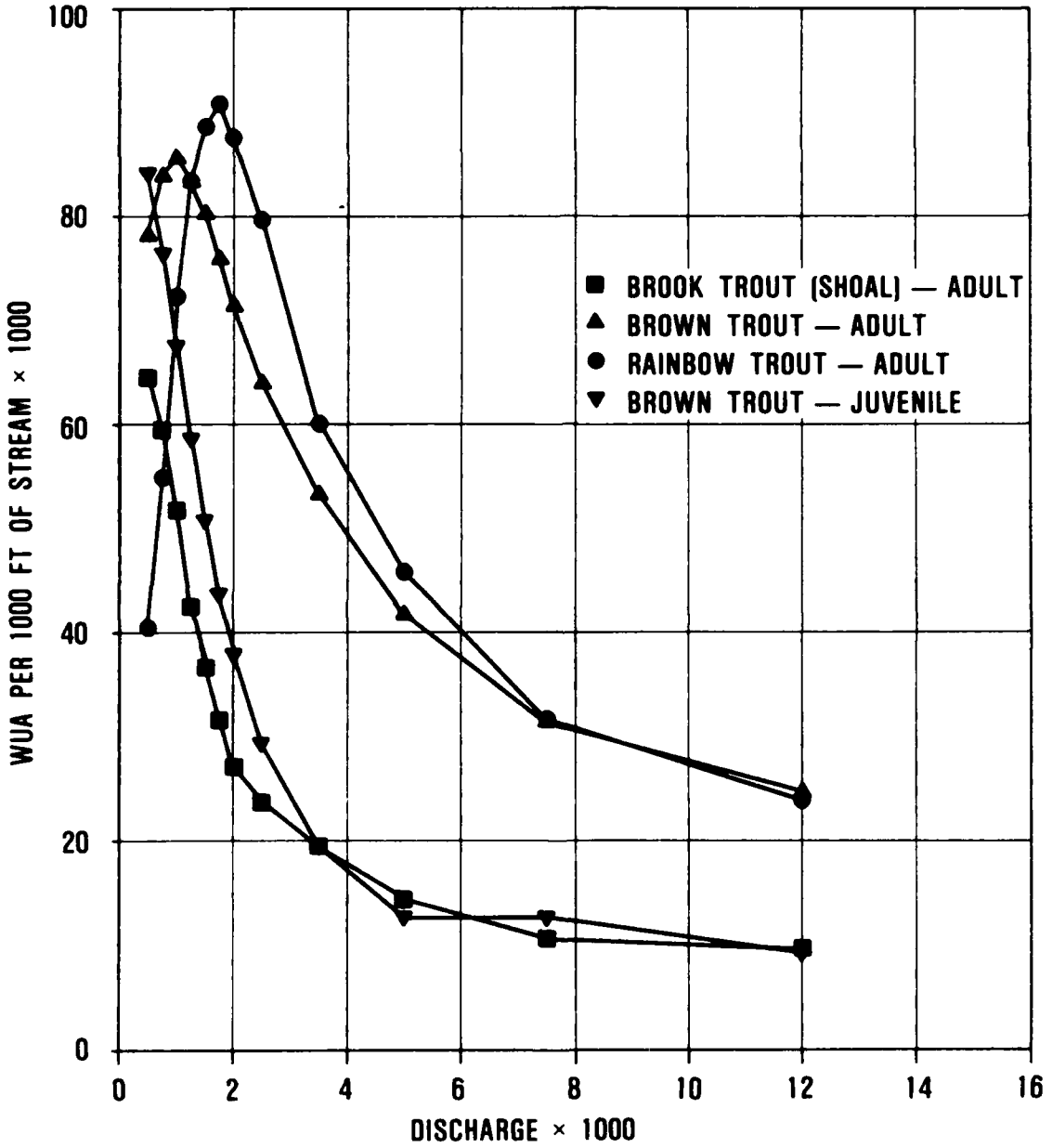


Figure 7. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for trout life stages for the major reach from Morgan Falls Dam to the confluence with Peachtree Creek

declined to a minimum at 12,000 cfs, with the rate of decline being much more rapid than for brown or rainbow trout. In general, the amount of habitat available for adult brook trout and juvenile brown trout is less than that available for either adult brown trout or adult rainbow trout.

61. The habitat value of the different major reaches differed substantially. The largest area of habitat for all trout species and life stages was found below Morgan Falls Dam (Figure 7), primarily because of the steep stream gradient, numerous shoals in this reach, and abundant cover provided by the large quantity of rocks, boulders, and exposed bedrock.

Adult brook trout habitat

62. Habitat for adult brook trout in the three major reaches peaked at a discharge near or under 1,000 cfs (Figures 5-7). For the reregulation pool reach and below Morgan Falls Dam, habitat decreased substantially for discharges greater than the optimum discharge. Habitat availability as a function of discharge dropped more gradually in the reach of river between the site of the proposed reregulation dam and the headwaters of Bull Sluice Lake. Although the habitat for adult brook trout for each major reach peaked at the lowest simulated discharge, there were several noticeable exceptions. For example, habitat in shoal areas, such as Jones Bridge, Island Ford, and Devils Race Course Shoals, usually peaked at discharges near 1,500 cfs (compare Figure 8 with Figures 5-7).

Adult rainbow trout habitat

63. Habitat for adult rainbow trout in the three major reaches peaked at a discharge between 1,500 and 2,000 cfs (Figures 5-7) and declined to a minimum at 12,000 cfs. The available habitat in all of the subreaches also follows the same trend, and no major differences were noted in the habitat-discharge relationship for this species at shoal and nonshoal areas (compare Figure 8 with Figures 5-7). The habitat value of the major reach below Morgan Falls Dam was greater than that of the two major upstream reaches, primarily because of the increased cover associated with the extensive shoals in this reach.

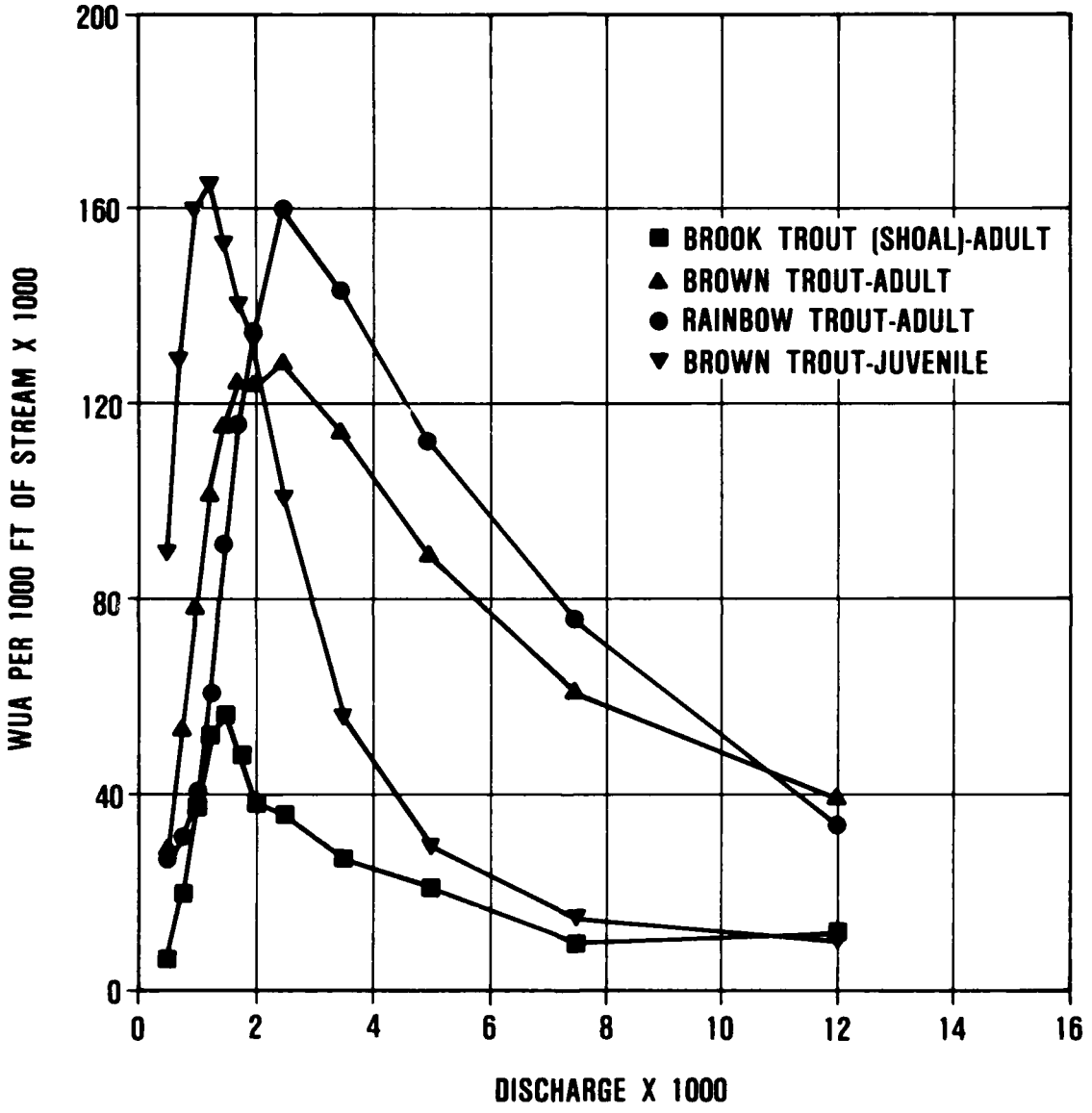


Figure 8. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for trout life stages for the subreach at Devils Race Course (river miles 305.86-305.92). The results for this shoal area are generally similar to results found at the other shoal areas in the Chattahoochee River

Adult brown trout habitat

64. Habitat for adult brown trout followed the same general pattern observed for adult rainbow trout, except that it peaked at a slightly lower discharge, usually around 1,000 cfs, in all major reaches (Figures 5-7). Again, the habitat-discharge relationship declined from the peak at 1,000 cfs to a minimum at 12,000 cfs. The habitat value of the major reach below Morgan Falls Dam was greater than that of the two upstream reaches, primarily because of the increased cover associated with the extensive shoals found in this reach. There does not appear to be a major difference in the habitat-discharge relationship among the subreaches that comprise the major reaches, although the shoal areas tend to have a more flattened peak (compare Figure 8 with Figures 5-7).

Juvenile brown trout habitat

65. The habitat-discharge relationship observed for juvenile brown trout was similar to that observed for brook trout. In general, habitat for each major reach peaked at or near the lowest simulated discharge (500 cfs). The habitat value of the major reach below Morgan Falls Dam was greater than that of the other reaches, again primarily because of the increased cover provided by the shoals (Figures 5-7). A substantial difference was noted between several of the subreaches and the values obtained for the major reaches. Habitat in the shoal areas (Devils Race Course, Island Ford, and Jones Bridge Shoals) either peaked at a discharge above 500 cfs but below 1,500 cfs, or the rate of decline in habitat with increasing discharge was less pronounced (compare Figure 8 with Figures 5-7).

Angling

General results

66. The results obtained for angling (see Figures 9-11) were not as consistent as the results obtained for trout life stages. However, angling activities can, like trout life stages, be broadly broken into two classifications. The WUA for both wade- and tube-fishing peaked at lower flows than low-power boat and nonpower boat fishing. Wade- and

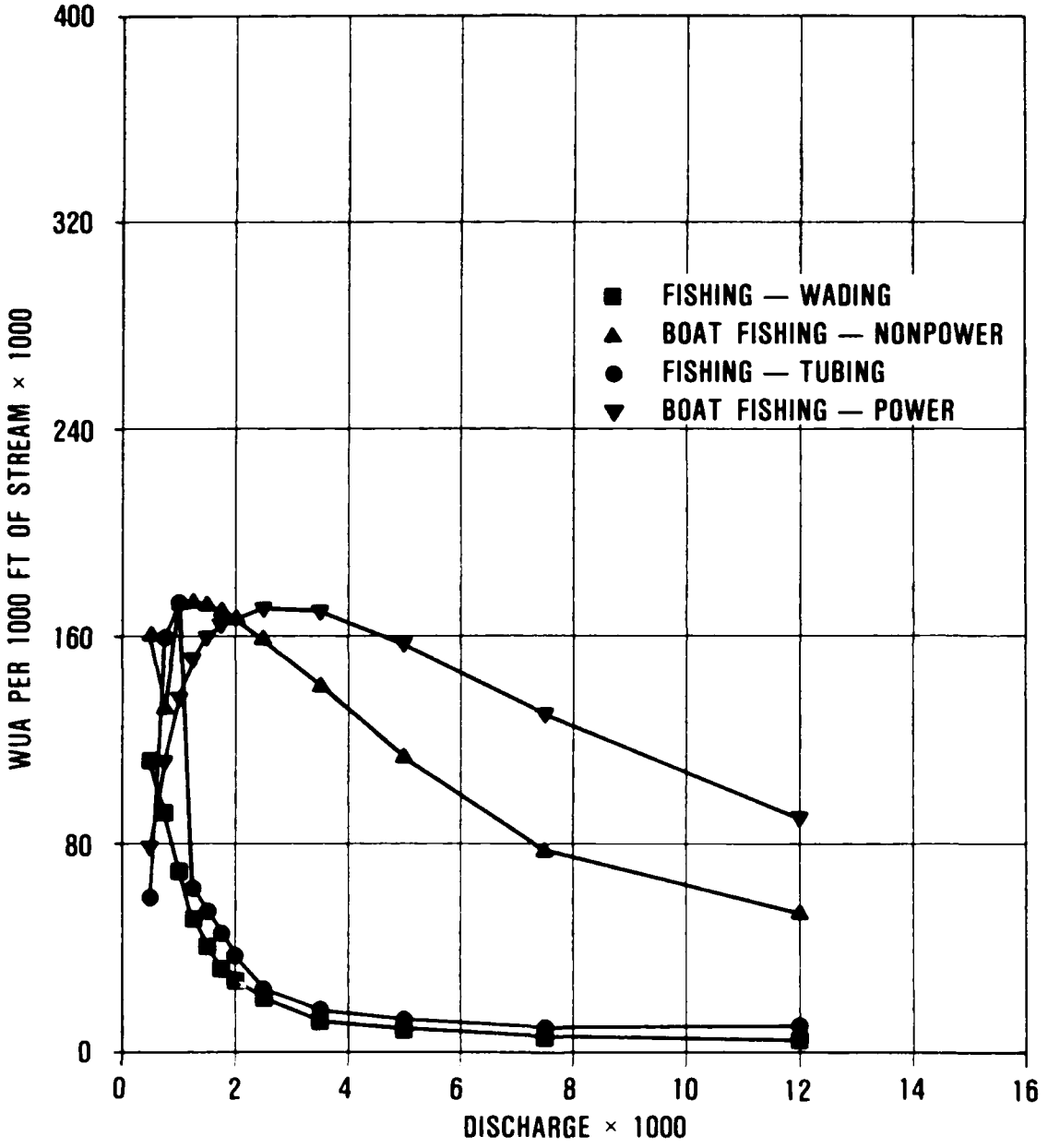


Figure 9. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for different types of angling activities for the major reach from Buford Dam to the site of the proposed reregulation dam

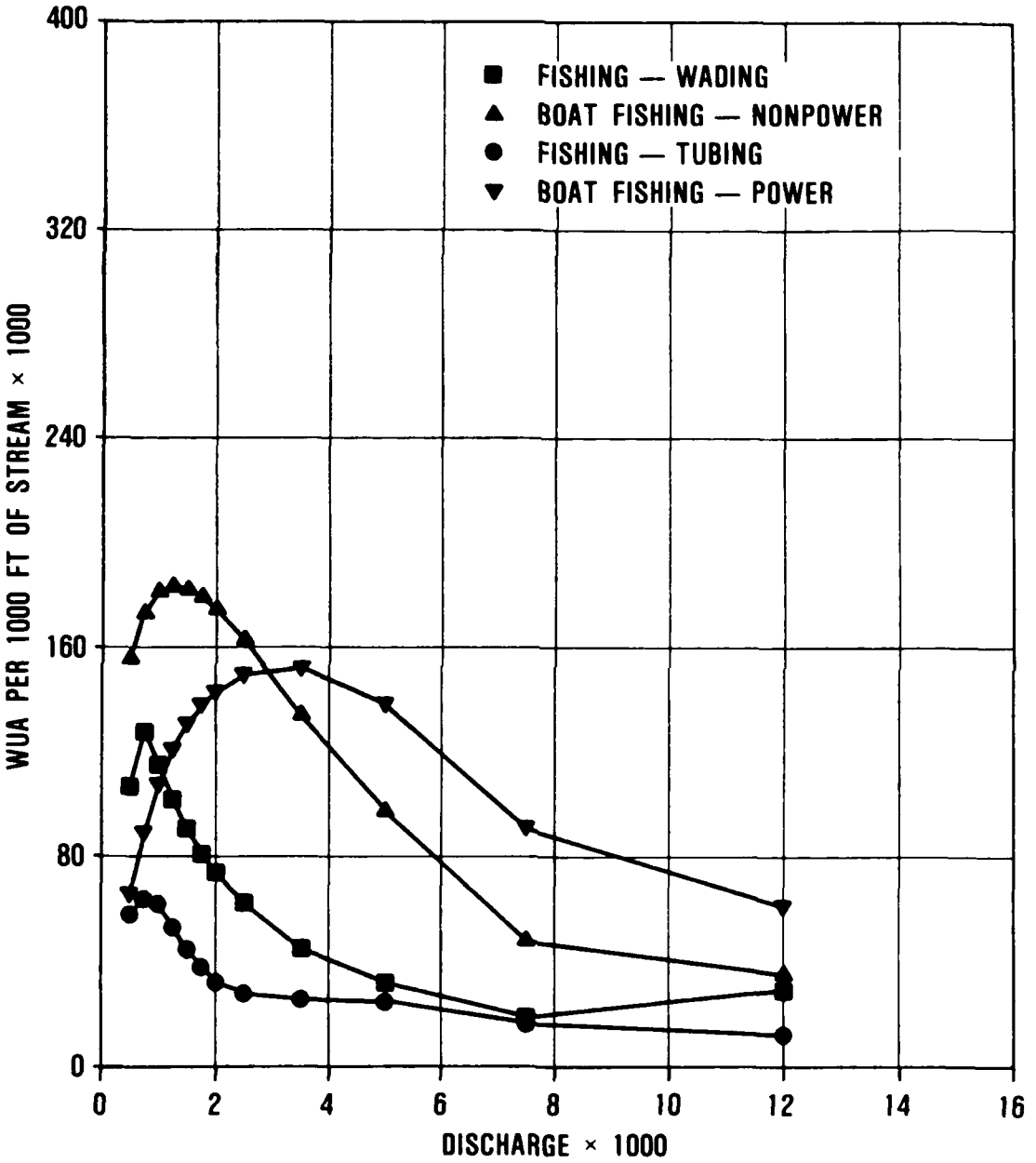


Figure 10. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for different types of angling activities for the major reach between the site of the proposed reregulation dam and the headwaters of Bull Sluice Lake

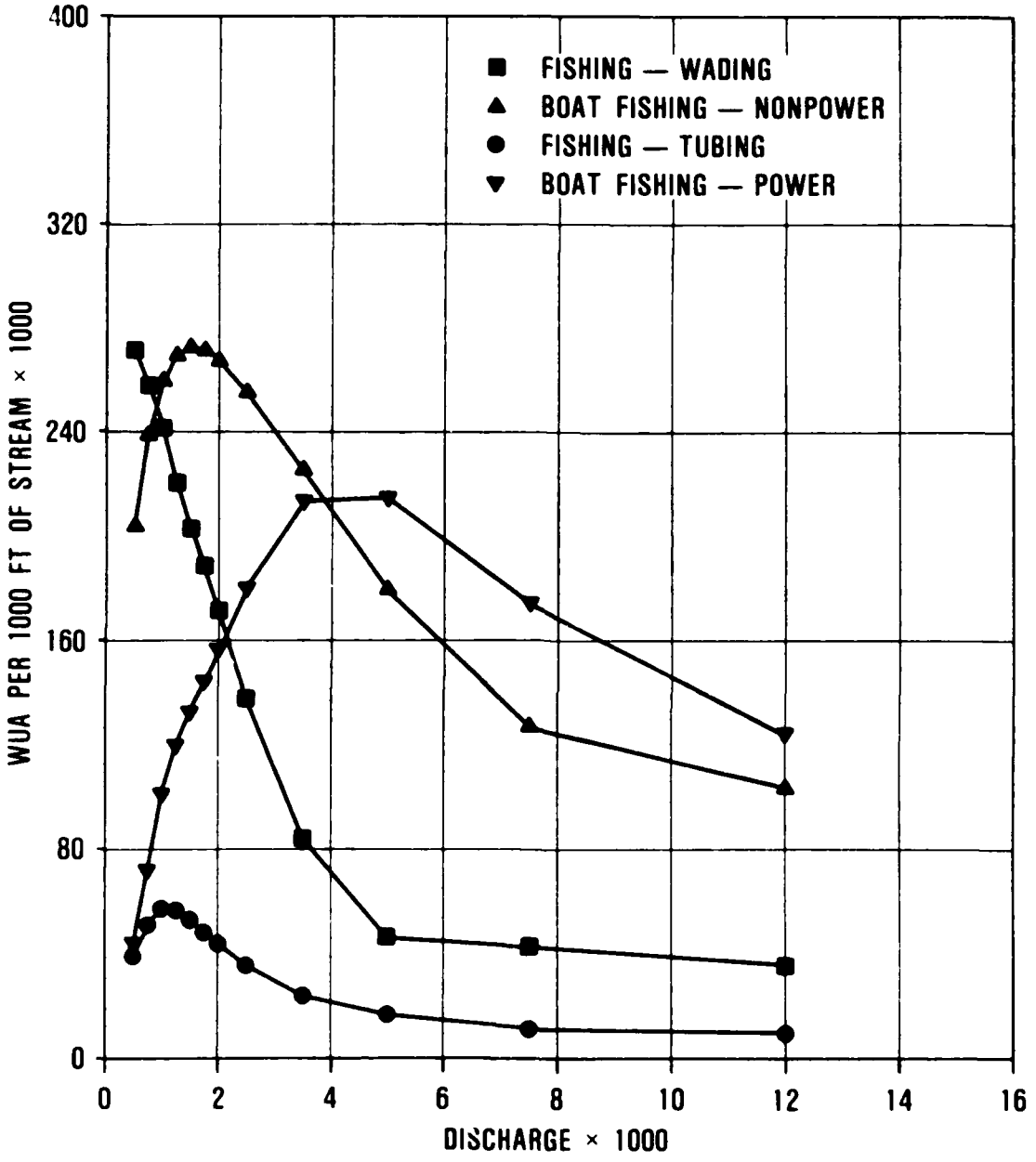


Figure 11. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for different types of angling activities for the major reach from Morgan Falls Dam to the confluence with Peachtree Creek

tube-fishing both peaked at or lower than a discharge of 1,000 cfs, whereas low-power boat and nonpower boat fishing peaked at a discharge greater than 1,000 cfs. The peaks for all activities occurred at a discharge of less than 5,000 cfs and declined to a minimum at 12,000 cfs. In all cases except tube-fishing, the highest WUA for angling activities occurred in the major reach between Morgan Falls Dam and Peachtree Creek.

Wade-fishing

67. The WUA for wade-fishing peaked at or below 750 cfs for each of the major reaches. In each case, WUA fell rapidly from the peak to a minimum at 12,000 cfs, particularly in the case of the major reach downstream from Morgan Falls Dam to Peachtree Creek (Figures 9-11). Also, WUA for wading declined substantially with increasing discharge. In each case, WUA for wade-fishing was reduced by a factor of two at or near a discharge of 2,000 cfs compared to the peak value at the lower discharge.

Tube-fishing

68. The curves presented for tube-fishing are restricted to the floating phase only and do not include the wading phase of this fishing activity. The results for tube-fishing are very similar to results presented for wade-fishing. In all cases, the optimum discharge for this activity occurs at or below a flow of 1,000 cfs, and WUA declines rapidly to a minimum at a discharge of 12,000 cfs. The WUA available for this activity at 2,000 cfs is considerably less than at 1,000 cfs.

Nonpower boat fishing

69. Peak WUA for this angling activity occurs at a discharge of 1,500 cfs and then drops off quickly in each of the major reaches (Figures 9-11). In the major reach downstream from Morgan Falls Dam, the drop in WUA with increasing discharge is less pronounced than the drop in WUA at the other two major reaches.

Low-power boat fishing

70. The WUA for low-power boat fishing increased with discharge to a peak between 2,500 and 5,000 cfs at each of the major reaches and then declined to a minimum at 12,000 cfs (Figures 9-11).

Recreation

General results

71. Excluding fishing, four types of recreational activities were examined in this analysis: wading, canoeing, rafting, and hanging-out. Unlike the results obtained for fish life stages, there were no consistently optimal flows for all recreational activities (Figures 12-14). The optimum simulated flows varied from a minimum of 500 cfs, required for raft-landing, to a maximum of 12,000 cfs, for midlevel rafting and canoeing.

72. The peaks in WUA for wading, hanging-out, and raft-landing (activities in which the water surface elevation is an important consideration) occur near or within the range of the present and anticipated flow regimes in the river (between 750 and 2,000 cfs). Table 10 presents water surface elevation as a function of discharge for cross sections in several important subreaches.

Wading

73. The WUA-discharge relationship for recreational or water-contact wading was identical to the WUA-discharge relationship for wade-fishing (Figures 9-11), since both activities are based on the same depth and velocity criteria (Appendixes B and C). Like wade-fishing, the amount of WUA for water-contact wading decreased substantially with increasing discharge.

74. Between 1,000 and 1,500 cfs, the percent change in WUA for wading differs greatly by major reach. From Buford Dam to the proposed reregulation dam, the WUA decreases by almost one-half; however, between Morgan Falls Dam and Peachtree Creek, WUA decreases by only 17 percent.

75. The areas of greatest importance in terms of wading are the shoal areas, specifically Jones Bridge Shoals, Island Ford Shoals, and Devils Race Course and associated shoals. In all these areas, WUA increases from a discharge of 500 cfs to a maximum of between 1,000 and 2,500 cfs. For example, in the Devils Race Course Shoal area, peak WUA for water-contact wading occurs between 750 and 2,500 cfs depending upon location (Figure 15). In all cases, however, WUA remains close to peak

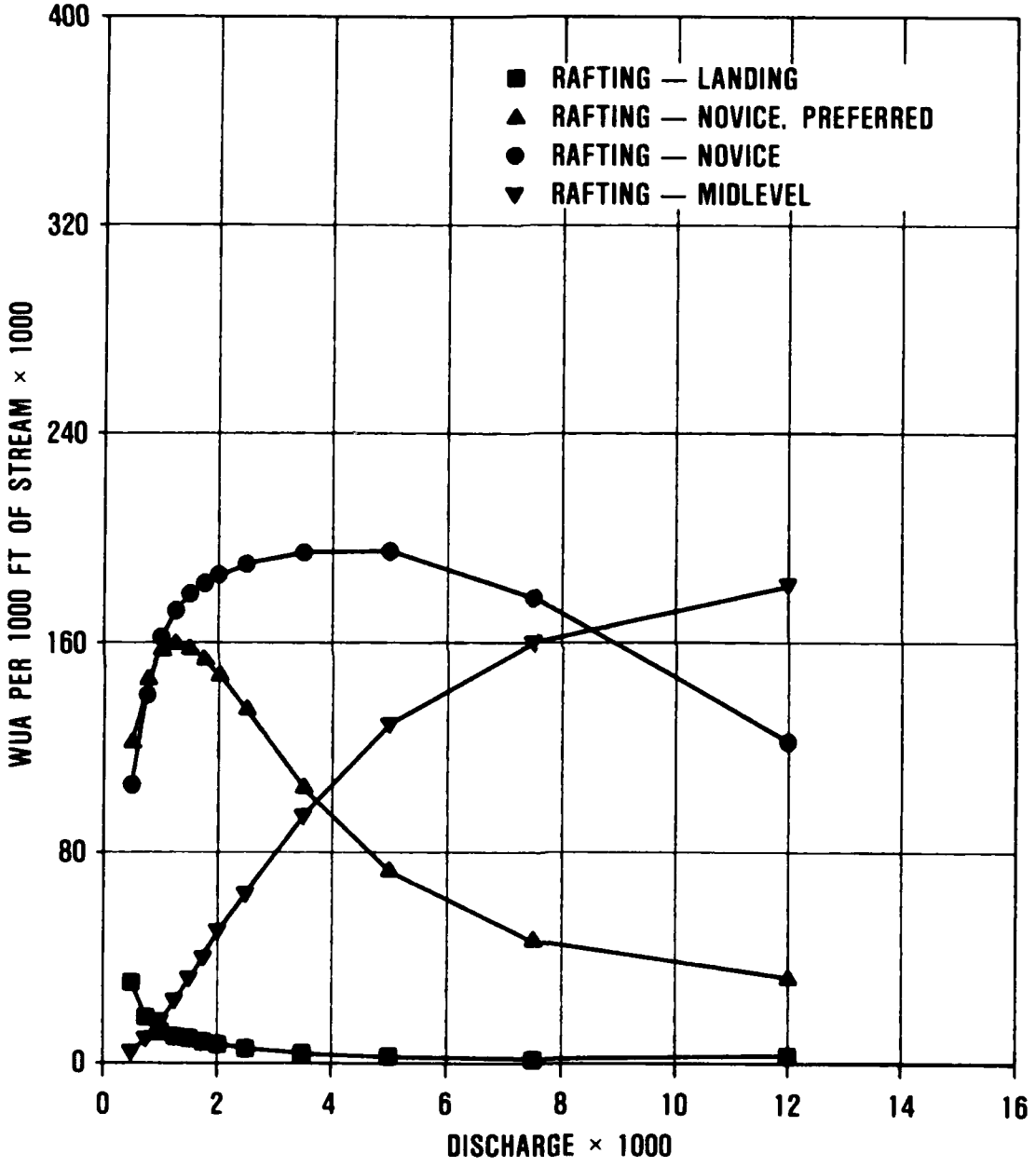


Figure 12. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for different types of rafting activities for the major reach from Buford Dam to the site of the proposed reregulation dam

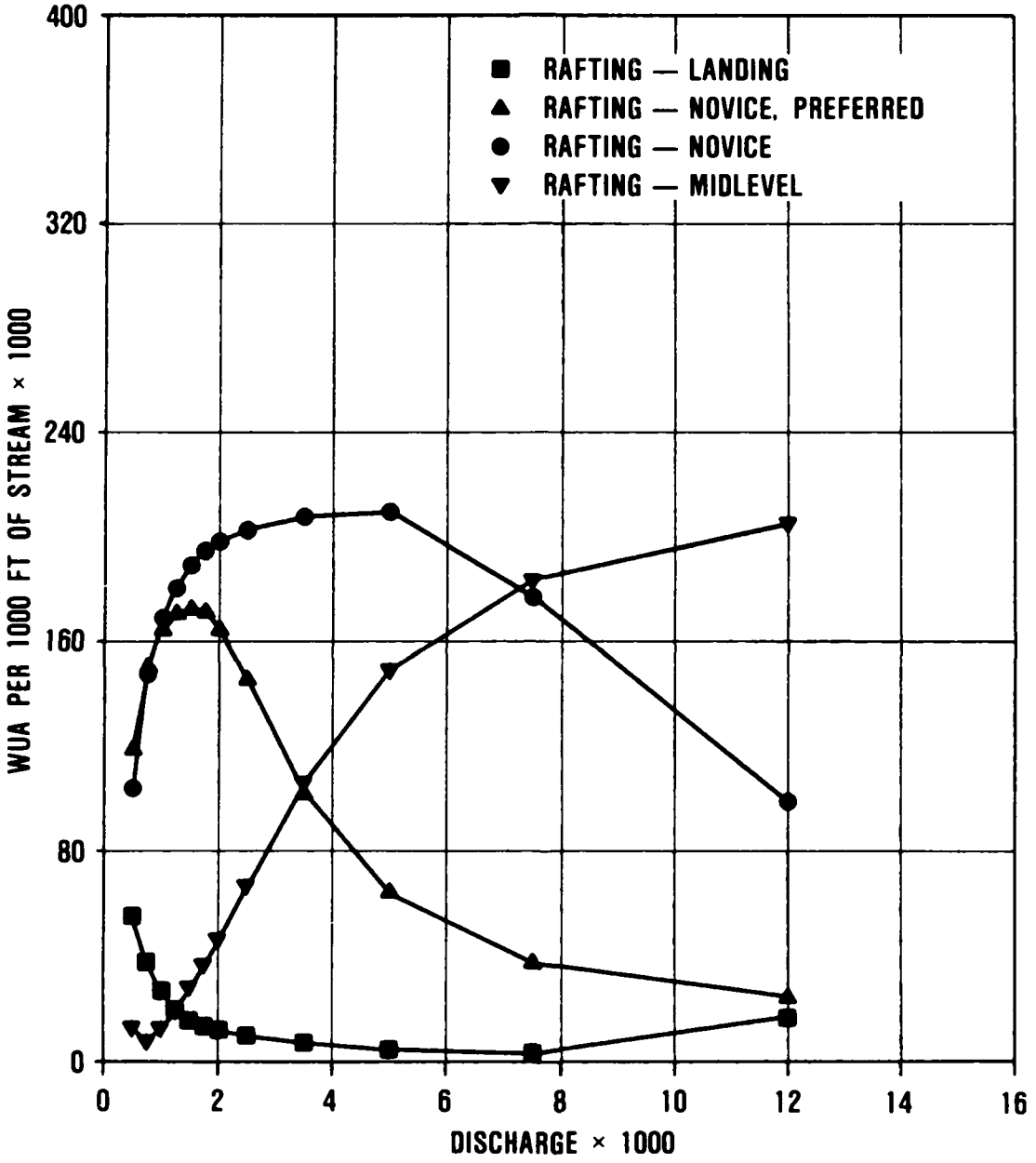


Figure 13. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for different types of rafting activities for the major reach between the site of the proposed reregulation dam and the headwaters of Bull Sluice Lake

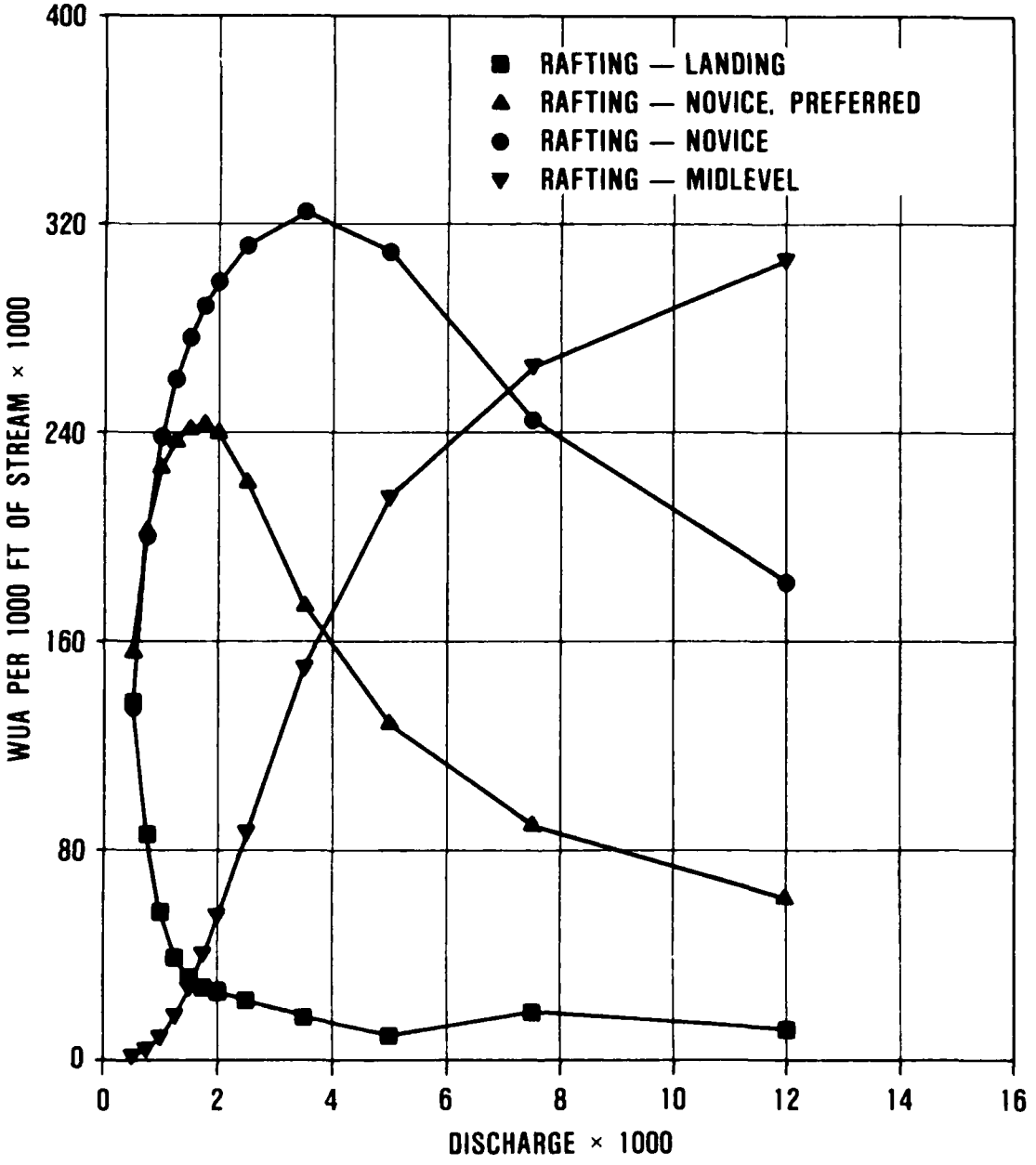


Figure 14. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for different types of rafting activities for the major reach from Morgan Falls Dam to the confluence with Peachtree Creek

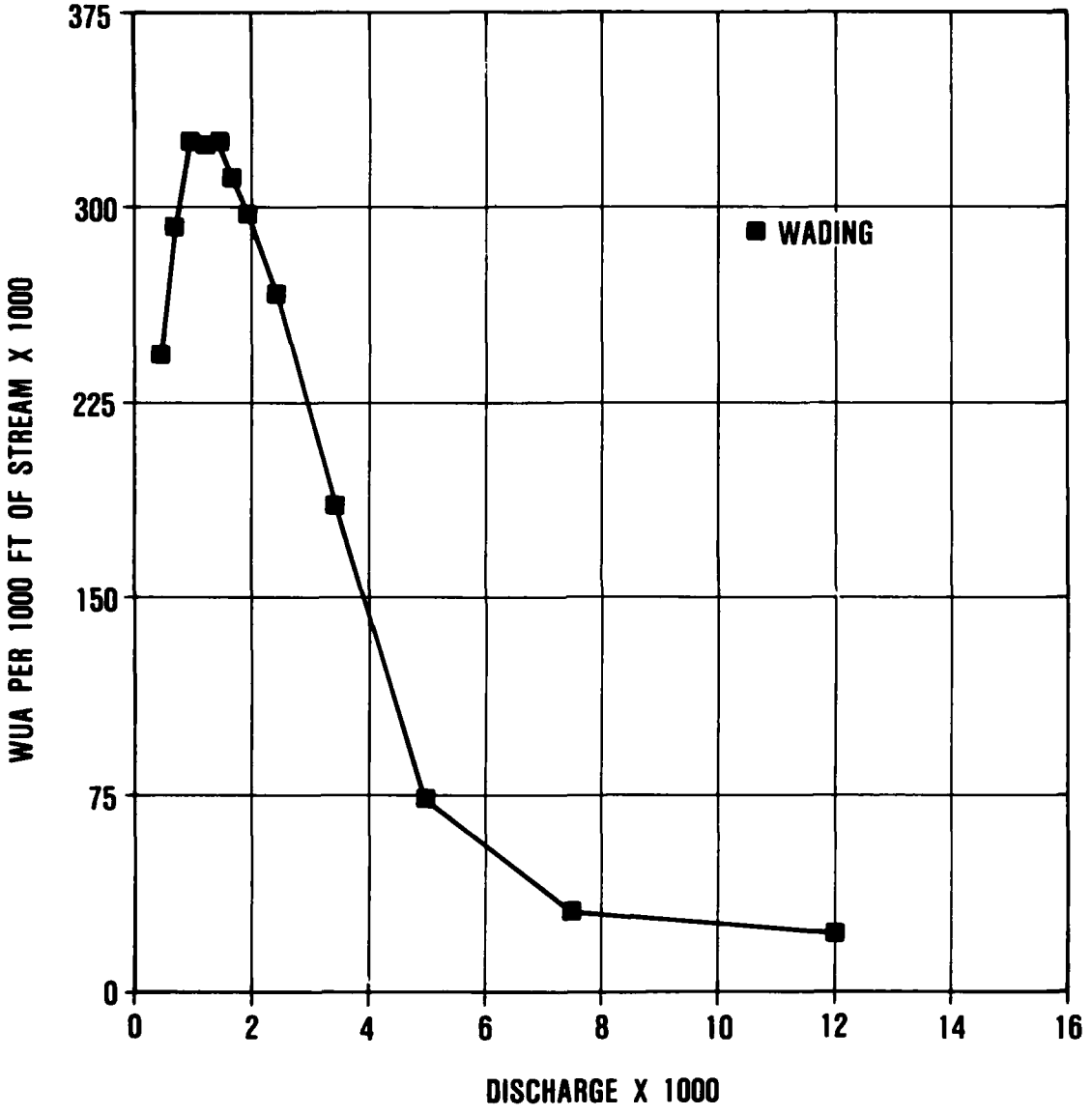


Figure 15. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for wading at the Devils Race Course subreach. Note the shift in optimal flows in this shoal area compared to the major reach summaries (Figures 12-14)

values up to discharges of about 3,500 cfs.

76. Paces Mill also receives some wading use, both as a separate recreational activity and also as part of raft-landing activities. Although WUA at Paces Mill decreases with increasing discharge, the decrease is relatively gradual up to a discharge of about 2,500 cfs.

77. Part of the reason for the relatively slow decrease in WUA for wading with increasing discharge at shoal areas and at Paces Mill is related to the stage-discharge relationship. At these sites, there is an increase in water surface elevation of only about 6 in. from 1,000 to 1,500 cfs and from 1,500 to 2,000 cfs (Table 10).

Rafting

78. Three different categories of rafting--novice-preferred, novice, and midlevel--were included to reflect the different skill levels of this user group. A fourth activity, raft-landing, was included since an important part of the rafting experience on the Chattahoochee River involves socializing with other users. Rafters often socialize by landing their rafts in the shoal areas and along the riverbanks. Thus, both the ease with which a raft can be landed and the amount of space available for landing affect the quality of the recreational experience.

79. The optimum flow required for each of these rafting categories varied over the entire range of simulated flows (Figures 12-14). As could be expected, midlevel rafting requires the highest flow, while raft-landing requires the lowest. The two categories of novice rafting fall in between, relatively close to each other. For all three rafting categories, the maximum amount of WUA is found in the major reach between Morgan Falls Dam and Peachtree Creek.

80. Raft-landing. The WUA for landing decreases as discharge increases since raft-landing requires relatively shallow water and low velocities. The decrease in WUA with increasing discharge is rapid, as increasing depth and velocity render the shallow areas and shoals unusable. Once discharge reaches 2,000 to 3,000 cfs, however, WUA remains relatively constant as only the shoreline is available for raft-landing and the shoal areas become unusable.

81. The greatest amount of WUA at low flows is found in the shoal

areas; hence, the section from Morgan Falls Dam to Peachtree Creek offers the greatest WUA of the three major reaches. The least amount of WUA occurs in the major reach from Buford Dam to the proposed reregulation dam, probably because of the narrower channel and steep banks.

82. Much of the raft-landing activity takes place at Paces Mill, where many rafters conclude their rafting trip and return rented rafts to the concessionaire. Landing is facilitated at this location by a large sand/gravel bar at the end of the boat ramp. The WUA for raft-landing in this location decreases substantially for discharges above 500 to 1,000 cfs (which are generally below present minimum flows in the channel). Above this discharge, however, WUA decreases only slightly to a discharge of about 2,500 cfs. These results can be explained by reference to the cross section taken immediately downstream of the raft ramp and across the sand/gravel bar (Figure 4), where most raft-landing activity occurs. The sand/gravel is exposed at discharges of up to 1,500 cfs and half-exposed at a discharge of 2,000 cfs. The inflection point in the rate of decline for the WUA-discharge relationship occurs at the discharge where the water surface begins to encroach on the sand/gravel bar.

83. Aerial photography of the sandbar at Paces Mill at different discharges supports the conclusions drawn from the PHABSIM analysis. Photographs taken at 1,050 and 1,500 cfs indicate little change in the surface area of the sandbar available for raft-landing. Also, there is only about a 12-in. increase in stage between 1,000 and 2,000 cfs (Table 10), providing further evidence that raft-landing at Paces Mill would not be substantially affected by flows between 1,000 and about 2,000 cfs.

84. Novice-preferred rafting. As discharge increases, the WUA for novice-preferred rafting increases to a maximum and then decreases rapidly (Figures 12-14). In the major reach from Buford Dam to the proposed reregulation dam, this maximum occurs at a discharge of 1,250 cfs; at the major reach from Morgan Falls Dam to Peachtree Creek, it occurs at a higher discharge, 1,750 cfs. The peak in WUA at the remaining major reach, between the site of the reregulation dam and the headwaters

of Bull Sluice Lake, occurs at a discharge near 1,500 cfs.

85. Novice rafting. The general shape of the WUA-discharge curves for novice rafting is similar to the shape of those presented for novice-preferred rafting. However, the maximum WUA occurs at much higher discharges, and the curves fall off less steeply following the peaks (Figures 12-14).

86. Midlevel rafting. In all three major reaches, the WUA for midlevel rafting increases as discharges increase. However, the high flow requirement for optimum midlevel rafting is probably somewhat misleading, since at the higher flows most of the shoal areas are completely submerged. Thus, the river surface is slick and the experience of rafting through a diversity of hydraulic conditions is not available.

Canoeing

87. General results. As with rafting, canoeing was divided into novice and midlevel categories to reflect the different skill levels of canoeists. Again, WUA for the novice category is optimal at discharges lower than the midlevel category (Figures 16-18). The maximum WUA for both novice and midlevel canoeing occurs between Morgan Falls and Peachtree Creek. For two of the cross sections, river miles 305.11 and 305.44, WUA for canoeing does not rise above zero until a discharge of 1,250 cfs is reached, indicating that low flows may significantly impede canoeing. This result reflects the experience of members of the CRIFS team when they canoed and boated through the shoals on the river. Passage of canoes through some of the shoal areas was difficult at the lower discharges.

88. Novice canoeing. The optimum WUA for novice canoeing on all three major reaches occurs between 1,500 and 2,000 cfs (Figure 16-18).

89. Midlevel canoeing. In all three major reaches, the WUA for midlevel canoeing increases substantially as flows increase until a flow of about 7,000 cfs is reached (Figures 16-18). Although increasing discharges provide for more WUA for midlevel canoeing, canoeists using the river at the very high flows will encounter the same lack of diversity in river hydraulic conditions as noted for midlevel rafting as the shoal areas are covered by the rising water.

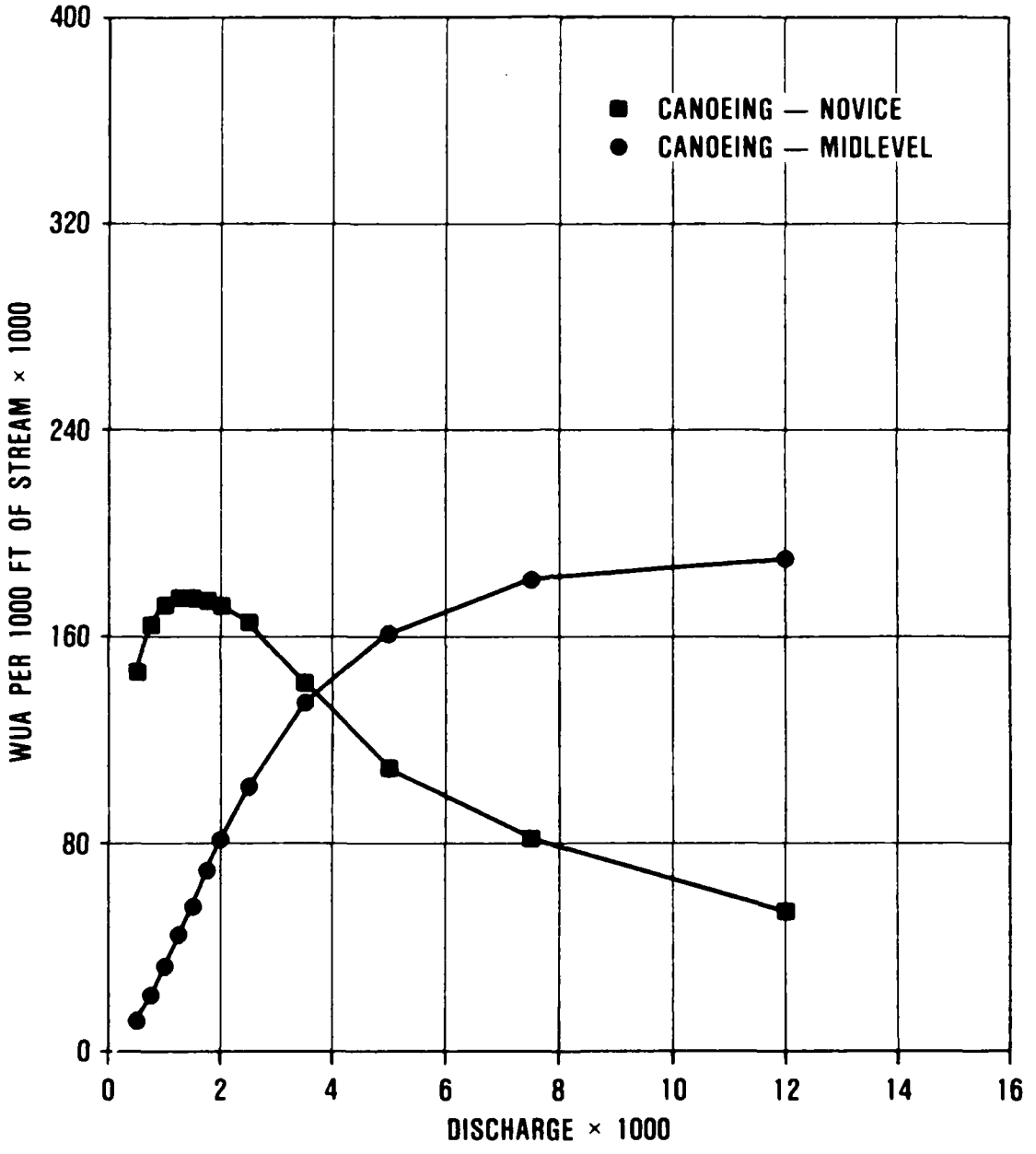


Figure 16. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for novice and midlevel canoeing for the major reach from Buford Dam to the site of the proposed reregulation dam

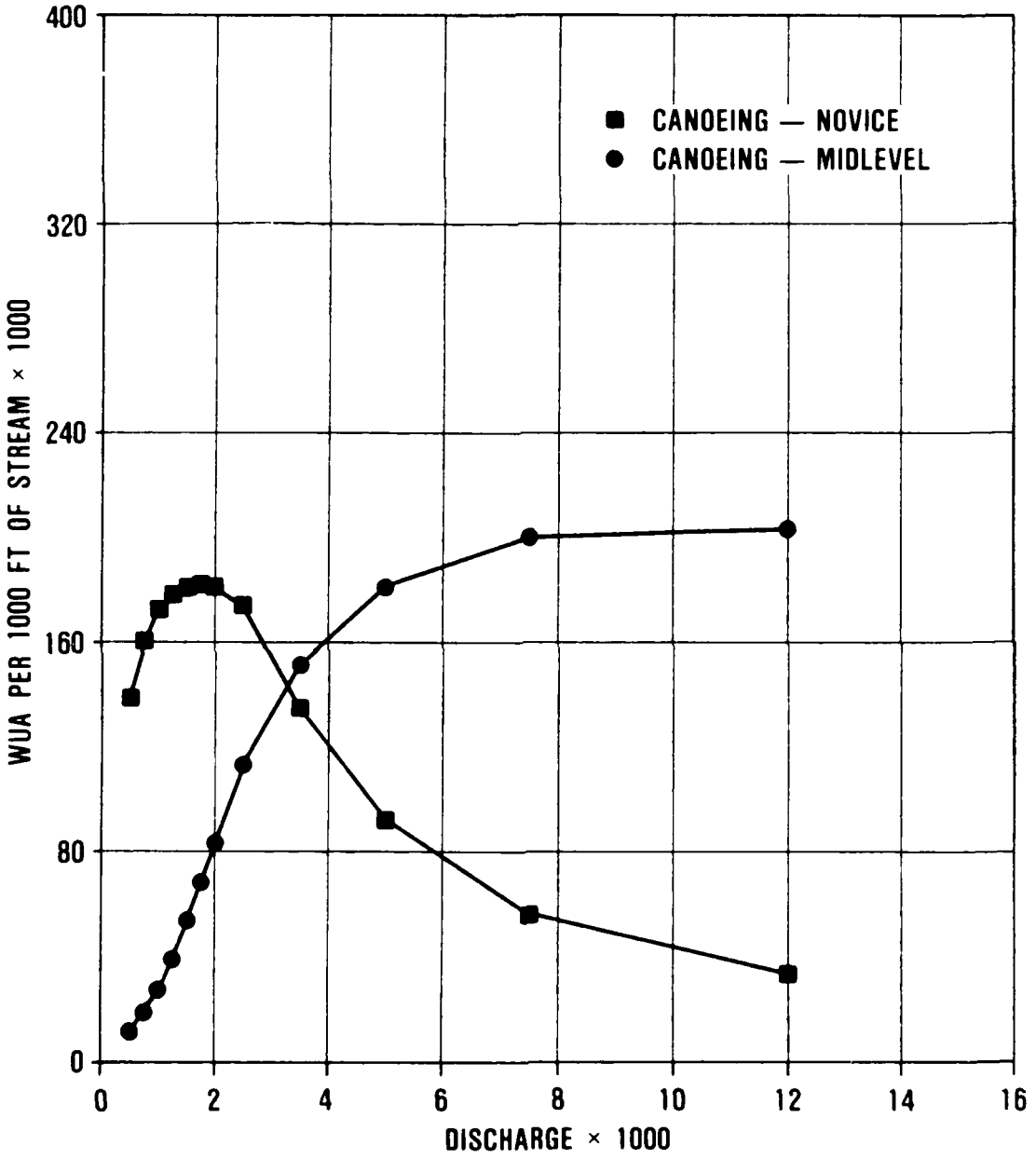


Figure 17. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for novice and midlevel canoeing for the major reach between the site of the proposed reregulation dam and the headwaters of Bull Sluice Lake

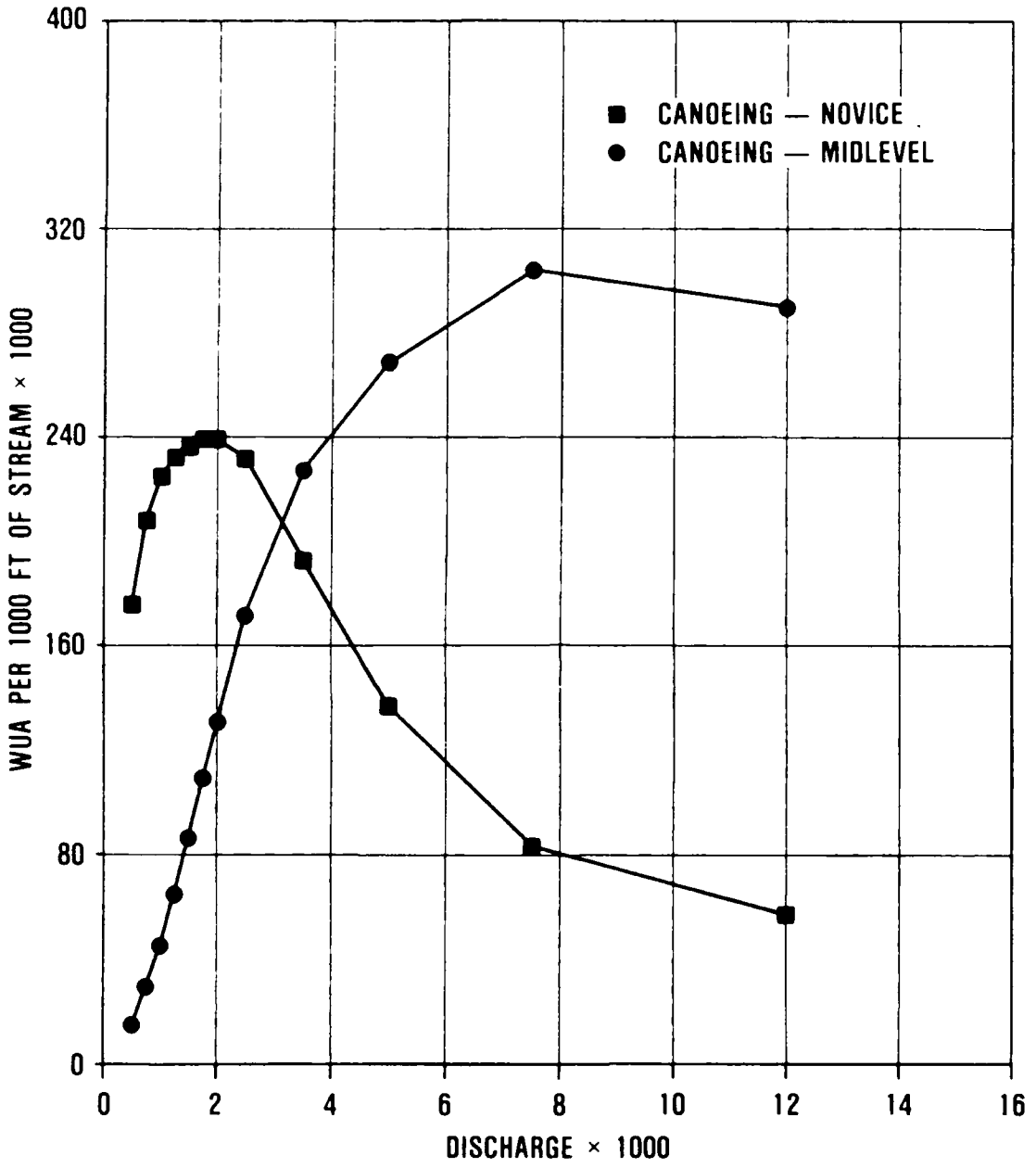


Figure 18. Relationship between WUA (presented as the average WUA for 1,000 ft of stream channel) and discharge for novice and midlevel canoeing for the major reach from Morgan Falls Dam to the confluence with Peachtree Creek

Special recreation topics

90. Hanging-out. Hanging-out is accommodated both on the banks of the river and on the rocks in the shoal areas. Bank use is relatively unaffected by changes in discharge, except perhaps that access to bank hanging-out sites from the river is affected because raft-landing becomes increasingly more difficult at the higher flows. Use of emergent rocks for hanging-out will be affected by increases in discharge both because the rocks become covered by the rising water and because flows increase to the point that landing a raft or canoe becomes difficult. The results of this study indicate that there is relatively little change in available hanging-out area on the rocks at the lower flows. Comparison of aerial photographs of the river downstream from Morgan Falls Dam taken at discharges of 1,050 and 1,500 cfs indicates no noticeable difference in the amount of rock surface area available for hanging-out.

91. Relative travel times. Relative travel times are given in Table 11 as the ratio of the travel time for a given discharge to that at a reference discharge of 1,000 cfs. For example, a discharge of 2,000 cfs would probably shorten a float trip from Morgan Falls to Peachtree Creek by a factor of 0.71 compared to the travel time at a discharge of 1,000 cfs. This table can also be used to relate observed travel times at a given discharge to travel times at other discharges. For example, the travel time for a raft from Powers Landing to Paces Mill is observed to be 5 hr at a discharge of 1,250 cfs. The travel time for a raft at 3,500 cfs should be proportional to the relative travel times at these two discharges. This can be calculated as

$$\text{Time (at 3,500 cfs)} = 5 \text{ hr} \times \frac{0.48}{0.88} = 2.7 \text{ hr}$$

Note that the travel time for a raft may differ considerably from the travel time for a parcel of water moving between the same two points on the river. However, the difference in travel times for a raft should be proportional to differences in travel time for a parcel of water, all other factors being equal. Relative travel times for the Chattahoochee

River between Morgan Falls Dam and Peachtree Creek are provided in Figure 19.

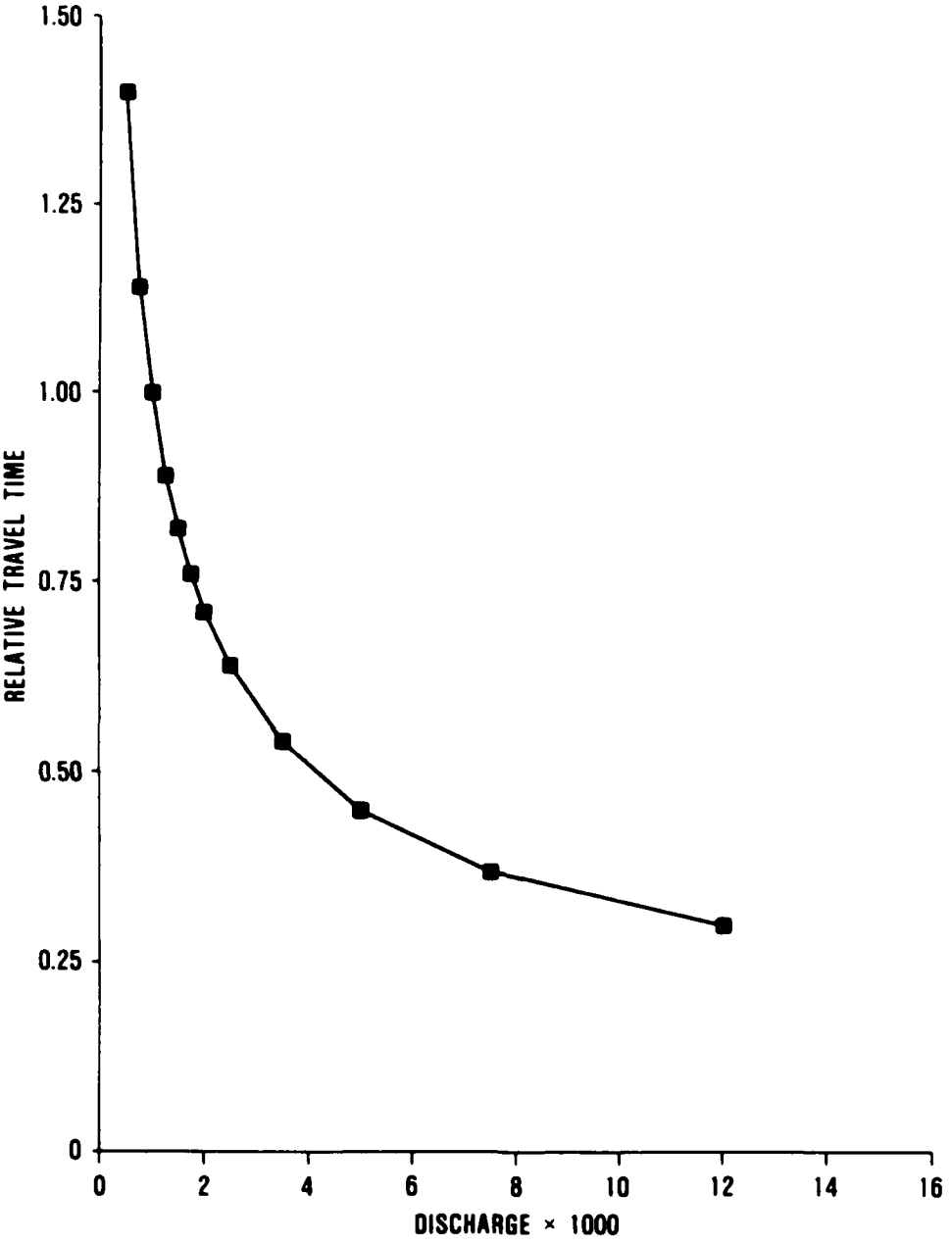


Figure 19. Relative travel time in the Chattahoochee River from Morgan Falls Dam to Peachtree Creek (reference discharge is 1,000 cfs)

PART IV: DISCUSSION

Comparison and Evaluation of Reaches

92. The 48-mile reach of the Chattahoochee River investigated in this study may, at any one time, be subjected to different flow regimes along its length because of:

a. Local inflows and withdrawals.

b. The time of travel required for flows to move through the system. For example, a release optimum for angling in the most upstream major reach may not travel to the lower reach until the following night.

c. The operation of Morgan Falls Dam.

d. The potential construction of a reregulation dam below Buford Dam.

93. The potential for differences in flow to occur along the length of the river requires a prioritization of the major reaches of the river to ensure that management plans developed for the system are targeted to the most valuable portions of the river. The following paragraphs prioritize the three major reaches identified in this study. It must be emphasized that just because a major reach receives the lowest priority does not mean that is of no value. Rather, it means that in a situation in which a target cannot be simultaneously optimized in each major reach, the target should be optimized in the reach of highest priority.

Trout habitat

94. The best habitat for trout is concentrated in the shoal areas of the river. The major reach downstream of Morgan Falls Dam to Peachtree Creek provides the most valuable habitat because it is composed of the highest percentage of shoals (nearly 40 percent). In addition, the habitat requirements of many trout-food organisms are similar to the habitat requirements of trout; thus, these shoal areas are also valuable from the standpoint of trout-food production.

95. The other two major reaches are not composed of the same high percentage of shoal area as is the most downstream reach. Thus, from

both a habitat and fish-food production standpoint, the reach from Buford Dam to the site of the proposed reregulation dam and the reach between the headwaters of Bull Sluice Lake and the site of the proposed reregulation dam should be of a lower priority.

96. Two areas of prime habitat, Jones Bridge Shoals (river mile 328.6) and Island Ford Shoals (river mile 319.5), occur within the major reach between the site of the proposed reregulation dam and the headwaters of Bull Sluice Lake. Additional short shoal areas, particularly downstream of Medlock Bridge, also provide habitat for trout. These shoal areas warrant special consideration in the development of a management plan for the Chattahoochee River. Although the Chattahoochee River from the site of the reregulation dam to Medlock Bridge has less trout habitat than the other reaches, it does support some angling activity, particularly where trout are stocked, and provides some habitat for trout.

97. The major reach between Buford Dam and the site of the proposed reregulation dam contains one shoal area immediately downstream of the dam, Bowmans Island Shoals (river mile 347.5). This shoal area provides optimum trout habitat on a seasonal basis when water quality is not limiting. This shoal area is, however, relatively short (less than 1 mile long). Several additional small shoal areas are also found elsewhere in this major reach.

Angling

98. Angling is concentrated at areas where access is provided and where trout are abundant. Trout are abundant in the shoal areas, because of increased cover and food production, and in areas where they are routinely stocked. Again, like trout habitat, angling is concentrated at the shoal areas, which are most prevalent in the reach downstream of Morgan Falls. This reach is nearest population centers, thus reducing the travel time of fishermen, and has a number of access points. Trophy brown trout are occasionally taken in the reach downstream of Morgan Falls Dam. From the standpoint of trout habitat, and perhaps potential wade-fishing opportunities, the most valuable reach is the lowest major study reach.

99. Of the remaining two major reaches, the reach between the site of the proposed reregulation dam and the headwaters of Bull Sluice Lake is the next most significant because of the presence of two extensive shoal areas, Jones Bridge Shoals and Island Ford Shoals, and other small, localized shoal areas. The shoal areas are popular for wade- and tube-fishing. Although the nonshoal portions of this reach do not provide the quality trout habitat provided by the shoal areas, they do receive considerable fishing pressure by bank and boat fishermen at points in the reach where catchable-sized trout are stocked. Changes in stocking practices in the three major reaches could potentially provide alternate angling opportunities.

100. The major reach between the site of the proposed reregulation dam and Buford Dam should receive the lowest priority for angling since total habitat for trout is less. Only one relatively short (about 1-mile-long) shoal area, Bowmans Island Shoals, occurs in this major reach.

Recreation

101. The reach between Morgan Falls Dam and the confluence with Peachtree Creek is the most important of the major reaches for support of nonangling recreation. A number of factors contribute to the importance of this major reach. The extensive shoal areas that characterize this major reach are a popular place for rafters and canoeists to land their vessels, congregate, and socialize. This major reach is in proximity to many potential users, since it is nearer to metropolitan Atlanta than the other two major reaches. A number of parks are available to facilitate access to the river. Additionally, several major apartment complexes provide shoreline access to residents. Concessionaire facilities at several of the parks in this major reach provide users with raft rentals, shuttle bus service, and other support facilities.

102. The major reach between the site of the proposed reregulation dam and the headwaters of Bull Sluice Lake is the next most important in terms of nonangling recreation. Again, the two extensive shoal areas, Jones Bridge Shoals and Island Ford Shoals, provide an area

suitable for wading, swimming, rafting, and canoeing, although the support facilities are not as extensive, particularly at Island Ford Shoals. Future demand for and use of these resources can be anticipated with growth of the surrounding populations and the potential for displacement of users from the most downstream major reach because of overcrowding. Some development is now occurring in this major reach which will provide additional recreational facilities and access.

103. The major reach between the site of Buford Dam and the site of the proposed reregulation dam should receive the lowest priority for nonangling recreation. The natural resource settings, river conditions, and lack of support facilities here are less conducive to nonangling recreational use than at the other two reaches. This major reach does have potential for development since the National Park Service manages a large section of land at the northern end.

Effects of Flow Alterations

104. Efforts to meet the projected water supply needs for the metropolitan Atlanta area, primarily by increasing the current minimum flows in the river, will impact fish habitat, angling, and recreation. The following paragraphs describe the effects of flow alterations on these beneficial uses of the river.

Trout habitat

105. The potential effects of flow alterations in the Chattahoochee River can be broadly classified as fish habitat modifications resulting from changes in depths and velocities, water quality changes caused by construction of the proposed reregulation dam (operation of a reregulation dam will slow the travel time of water through the system, thereby resulting in more warming of the water and increased water temperatures over current conditions), changes in cover in the channel, and changes in the channel itself (i.e., bank sloughing).

106. Under current operating conditions, trout habitat at any point within the entire study length of the Chattahoochee River varies between optimum and near-optimum at the lower flows (550 to 1,050 cfs,

depending upon location in the river) to a minimum at the higher discharges (near 10,000 cfs depending upon discharge from Buford Dam and local inflows). Additionally, habitat can vary from a maximum to a minimum several times in a 24-hr period. Thus, fish habitat may be optimal for much of the day and minimal for several hours. Under the proposed revised operating schedule, the minimum in habitat that occurs on a daily basis will be eliminated and the overall flow regime will more nearly approximate the optimum flow required by the four trout life stages.

107. The benefit to the fishery as a result of this change is difficult to quantify because the relative difference in habitat value between a steady flow and a fluctuating flow cannot be defensibly quantified. However, from a qualitative standpoint, considerable information exists suggesting that daily fluctuating flows are more detrimental to fishes than steady flows. In addition, steady flows in the river will be more conducive to increased production of primary (algae and aquatic macrophytes) and secondary (aquatic macroinvertebrates) than fluctuating flows. Neither aquatic vegetation nor aquatic macroinvertebrates will be subjected to alternate scour and stranding by fluctuating water levels under the revised operations to meet water supply needs. From a fish habitat standpoint, the revised flow in the river obtained by eliminating the peak flows associated with demand for power will be beneficial for the reaches downstream of the site of the proposed reregulation dam, assuming that detrimental water quality conditions do not occur.

108. The fish habitat benefits derived from flow alterations vary somewhat by life stage. The habitat available for juvenile brown trout and adult brook trout is negligible at discharges above 4,000 cfs. Thus, the elimination of the daily peaking flows would be of considerable benefit to the habitat available to these two species. This is particularly true if the success of these two life stages is limited by the lack of habitat at the high daily discharges. Discussions with representatives of the Georgia Game and Fish Division indicate that this may, in fact, be the case. Brook trout are not stocked in appreciable

numbers since this species has not provided the return rate (harvest) of rainbow and brown trout. Juvenile brown trout are stocked in the Chattahoochee River below Morgan Falls Dam. Based on the PHABSIM analysis presented in this report, habitat at a higher flow (1,000 to 1,500 cfs) is available at the shoal areas. An upward shift in the current minimum low flow to a more constant release may cause an overall moderate decline in habitat available at the lower discharges since both of these life stages have optimum habitat at a discharge lower than 1,000 cfs in all of the major reaches. However, since the optimum is somewhat higher in some of the subreaches, particularly in the widest shoal areas, some areas of good habitat will be available at discharges above the current minimum flow.

109. Firm conclusions concerning the effect of flow modification cannot be reached downstream of Morgan Falls Dam, since it is operated independently by Georgia Power Company. If Morgan Falls Dam is operated as a run-of-the-river project, in which discharges equal inflows, the trout fishery downstream from Morgan Falls Dam will be enhanced in much the same manner as the reach between Bull Sluice Lake and the site of the proposed reregulation dam. However, if Morgan Falls Dam is operated in pond-and-generate or in peaking mode, the effects of flow modifications could be considerably different.

110. If no reregulation dam is constructed and flows necessary to meet water requirements are obtained by modifying Buford Dam, the effects of these modifications on the trout fishery in the major reach between Buford Dam and the site of the proposed reregulation dam will be similar to the effects on the two major downstream reaches. However, if a reregulation dam is constructed, firm conclusions on habitat effects within the pool of the proposed reregulation dam cannot be made since the size, the storage-capacity/elevation relationship, and operational details of the reregulation dam are currently unknown. However, general effects of operating a reregulation dam on this reach will be determined by how low the water level drops within the pool of the reregulation dam. If the pool of the reregulation dam falls enough to dewater Bowmans Island Shoals and minimum flows from Buford Dam are stopped, then

much of the prime trout habitat in this major reach may be lost. The effects further downstream but within the pool of the reregulation dam cannot be estimated since the details of operation are unknown.

111. Water quality, particularly temperature, is a major concern downstream of Morgan Falls Dam and, in fact, in the summer may be of greater concern than the depths and velocities available for trout habitat, since lethal temperatures can occur at very low flows. Water quality modifications in the Chattahoochee River caused by operation of a reregulation dam are being addressed in a separate study by the US Army Engineer Waterways Experiment Station.

Angling

112. The potential effects of flow alterations in the Chattahoochee River can be directly related to the altered depths and velocity that anglers will encounter in their angling efforts. Under the existing flow conditions in the river, the potential for angling activities varies considerably between the minimum and maximum flow in the river and also by the type of angling activity, since the optimum flows for nonboat (wade- and tube-fishing) or boat (nonpower and low-power) differ considerably.

113. The potential for wade- and tube-fishing peaks at or near the current minimum low flow in each of the major reaches. However, wade- and tube-fishing become virtually impossible above a flow of approximately 4,000 cfs in the major reaches. Thus, these two types of nonboat angling are presently restricted to low-flow periods.

114. The potential for nonboat fishing (wade- and tube-fishing) will vary somewhat by major reach under the revised operating schedule. In the reach between the site of the proposed reregulation dam and the headwaters of Bull Sluice Lake, nonboat angling may be possible during all time periods (except under flooding conditions), but with some reduction in potential since the optimum flows for these activities occur at less than the anticipated flows in the river. The potential for angling activities under revised operating conditions in the major reach downstream from Morgan Falls Dam depends, like fish habitat, on how Morgan Falls Dam is operated. If it is operated as a run-of-the-river

project, the effects of the revised flows will be similar to the reach upstream of Bull Sluice Lake. However, if Morgan Falls Dam is operated in pond-and-generate or in peaking mode, the effects of flow modifications on angling could be considerably different. Predicting the effects of other than run-of-the-river operation of Morgan Falls Dam is outside the scope of this investigation.

115. The potential for nonboat angling in the major reach downstream from Buford Dam is dependent on whether the reregulation dam is constructed. The Bowmans Island Shoals area is popular for wade- and tube-fishing. If modified flows to meet projected water supply needs are released directly from Buford Dam, the effects on angling will be similar to those observed in the major reach downstream from the site of the proposed reregulation dam. If a reregulation dam is built to supply the necessary flows for water supply, the effects on angling will be determined by project operation. If minimum flows are no longer released from Buford Dam and the water level within the pool drops sufficiently, the Bowman Island Shoals area may be lost for angling due to dewatering as the volume in the reregulation pool drops to supply water downstream. Conversely, much of the Bowmans Island Shoal area may become unusable for wade- and tube-fishing if the pool becomes too deep during power generation at Buford Dam.

116. Under current operating conditions, the minimum flow occurs at considerably less than the optimum flow for power boat angling and near the optimum for nonpower boat angling in all major reaches. The decline in WUA for boat angling with increasing discharge is more gradual than for nonboat angling. Consequently, boat angling can occur even at discharges of 4,000 to 6,000 cfs.

117. Under the revised operating conditions, the potential for boat angling (power and nonpower) may vary somewhat by major reach. In the reach downstream from the site of the reregulation dam, conditions for boat angling will be generally improved since the optimum flow will be near the anticipated flow in the channel. The effects of modified flows downstream of Morgan Falls Dam will be determined by the operation of Morgan Falls Dam. If it is operated as a run-of-the-river project,

the effects will be generally similar to those observed for the major reach downstream from the site of the reregulation dam, although there will be less potential for power boat angling. The effects of other types of operation will vary depending upon release patterns.

118. The effects of flow modification on boat angling in the major reach downstream from Buford Dam will depend on whether a reregulation dam is constructed. If the reregulation dam is not constructed, the effects of flow modification on boat angling will be similar to those projected for the reach downstream of the site of the proposed reregulation dam. If the reregulation dam is constructed, the effects on boat fishing in this major reach will be partially determined by how low the water levels drop within the pool of the reregulation dam as determined by the operation of Buford Dam and the reregulation dam. Two detrimental effects on boat angling will be observed in this major reach if the pool of the reregulation dam drops enough to dewater Bowmans Island Shoals and minimum flows are not released from the dam. First, it will have a negative effect on boat fishing because the boat ramp used to access Bowmans Island Shoals is located in the dewatered reach. Second, since the trout in the dewatered reach will either move downstream or be stranded, there would be no motivation for angling. Boat angling within the rest of the reregulation dam pool would probably not be affected.

Recreation

119. Currently, a variety of recreational activities occur on the Chattahoochee River. Changes in streamflows will affect the WUA for these activities in different ways because of the differing depth and velocity requirements for each.

120. Canoeing. Under existing conditions, the minimum low flow provides less WUA than would be provided by increased flows. Therefore, a modified flow to provide water supply will probably have a beneficial effect on the amount of area available for both novice and midlevel canoeing. The elimination of generation flows that currently exist in the river system will also have a beneficial effect on novice canoeing since the high discharges are largely unusable for this activity. In

terms of midlevel canoeing, the greatest amount of WUA occurs at or near the highest simulated discharge. At these discharges, however, the shoals are covered and the river lacks the desired hydraulic diversity. Therefore, the optimum discharge, in terms of a satisfactory experience, would be somewhat lower than the highest simulated discharge.

121. The effects of increased flows for water supply on canoeing will vary by major reach. The current minimum releases can cause passage problems through the shoal areas for canoeists. Thus, canoeing in the major reach between Morgan Falls Dam and the confluence with Peachtree Creek, which is composed of a high proportion of shoal areas, may benefit considerably from increased flow in the river. In the other two major reaches, however, the effects of small flow increases will probably be negligible, except for the area of Jones Bridge Shoals and Island Ford Shoals. If the reregulation dam is constructed, the effects on canoeing in that portion of the river will be determined by the operation of the project. If the water levels fall below the boat ramp near Buford Dam, canoeing will become difficult in this major reach because of access and passage problems.

122. Rafting. The effects of flow alterations on rafting are more complex than the effects of flow alterations on canoeing since the total rafting experience is a composite of rafting, raft-landing, and raft takeout. The WUA for each of these different facets of rafting peaks at different discharges. For example, while the optimum discharge for novice-preferred rafting occurs near a discharge of 2,000 cfs, the optimum discharge for raft-landing occurs near a discharge of 500 cfs.

123. Any increase in streamflows will increase the WUA for both novice and midlevel rafting. The effects of flow alterations on raft-landing and takeout will generally be detrimental, but not to a large degree. Although maximum WUA for raft-landing in shoal areas and on riverbanks occurs at 500 cfs, the lowest simulated discharge, this is generally lower than current flows. Examination of aerial photographs taken at staged flows indicates that a negligible surface area of exposed rock is lost between a flow of 1,050 cfs and a flow of 1,500 cfs. However, with the aerial photographs it is not possible to extrapolate

the change in area with discharge above a flow of 1,500 cfs. Thus, to minimize loss of exposed rocks in the shoal areas, flows probably should not exceed about 1,500 cfs. Examination of the aerial photographs, results of the PHABSIM analysis, and field observations by the CRIFS team indicate that the sand/gravel bar at Paces Mill used for taking out rafts becomes mostly inundated at a discharge above 1,750 cfs but is still usable at a discharge of about 2,500 cfs.

124. Some decrease in float time will also occur with increasing flows. The proposed increase in minimum flows from 1,000 to 1,500 cfs would decrease float time by approximately 20 percent in the most downstream major reach. Many rafters currently lengthen their float trip by stopping at various points along the river. Therefore, rafters could possibly compensate for the increased minimum flow by stopping either more frequently or for longer periods.

125. Flow alterations will have a considerably different effect on each of the major reaches of the Chattahoochee River investigated in this study. Presently, rafting activity is concentrated in the major reach between Morgan Falls Dam and the confluence with Peachtree Creek because of availability of concessionaire facilities, presence of numerous access points, availability of park facilities, and the high percentage of shoals in this reach. The restrictions discussed in previous paragraphs, with regard to raft-landing and takeout, apply directly to this major reach. In general, any flow increase above current minimum flows will increase WUA for rafting. It will, however, decrease the area available for raft-landing and takeout. The amount of decrease appears to be minor at the flows being considered for water supply, although it is substantial at higher flows.

126. Flow alterations on the other two major reaches will not be affected to nearly the same degree as in the most downstream reach. These reaches have much less area for raft-landing and takeout at any flow. In addition, there is currently less rafting in these two reaches since they provide neither the park nor the concessionaire facilities of the most downstream major reach.

127. Wading. Since WUA for wading decreases as discharges

increase, it appears as though the proposed flow alterations would have a detrimental effect on wading. This, in fact, may not be the case. The major reach most affected by the increase in flows, Buford Dam to the proposed reregulation structure, currently receives very little wading use (most likely due to the channel shape and lack of public access). Most wading use is concentrated in the shoal areas of the other two major reaches. In the shoal areas, WUA for wading peaks between 1,000 and 2,500 cfs. Therefore, the proposed flow alterations would actually increase the space for wading in the areas where it is currently occurring. An analysis of the stage/discharge relationship for many of the cross sections showed an increase in water depth of only 1 ft from 1,000 to 2,000 cfs (Table 10).

128. Hanging-out. For the most part, hanging-out seems to occur in the shoal areas of the two downstream major reaches (probably for the same reasons cited under "Wading"). Use of the exposed rocks in the river for hanging-out is affected both by the amount of exposed rock and the ability of the users to wade out to these rocks. As described under "Rafting," the proposed flow increases should have a minor effect on the amount of exposed rock available. In addition, it appears as though wading will not be adversely affected in the shoal areas. Use of the banks for hanging-out is unlikely to be affected by the proposed flow increase in any of the three major reaches.

Conflict Identification

129. The Chattahoochee River is a valuable resource that is used by a variety of potentially competing user groups. Consequently, conflicts between user groups are inevitable. Use of the river for water supply has the potential to affect other uses of the river and, as this study has demonstrated, conflicts among the remaining users of the river may also arise. For example, there is a conflict between users engaged in wade- or tube-fishing and users engaged in boat fishing since the flows optimum for one type of angling are not optimum for another type of angling. Note that this does not mean that conflicting river uses

are mutually exclusive. Rather, it means that a flow optimum for one use may be suboptimum (but still possible) for another use.

130. Development of a reasonable management plan for the Chattahoochee River first requires identification of the user conflicts that could occur. Figure 20 presents a matrix of the conflict relationships (based upon optimum flow requirements) between potential angling, potential recreation, and trout life stages. Elements within the table were obtained by subtracting the optimum flows required for each pair of entries for each major reach. Summary values for the Chattahoochee

		TROUT				ANGLING				RAFTING				CANOEING		WATER SUPPLY
		BROWN JUVEN	TROUT ADULT	ADULT BROOK	ADULT RAINB	WADE	TUBE	BOAT NOPWR	BOAT POWER	NOVICE PREFR	MDLVL	LAND-ING	NOVICE	MDLVL		
TROUT	JUVEN BROWN		O	O	M	O	O	M	X	X	M	XX	O	M	XX	+
	ADULT BROWN			O	M	O	O	O-M	X	X	O-M	XX	O	M	XX	+
	ADULT BROOK				M-X	O	O-M	X	XX	X	M	XX	O	M	XX	+
	ADULT RAINBW					M	M	O	X	X	O	XX	M	O	XX	+
ANGLING	WADE						O	O-M	X	XX	M	XX	O	XX	XX	-
	TUBE							O-M	X	XX	M	XX	O	XX	XX	-
	BOAT-NONPOWR								X	XX	O	XX	M-X	O	XX	+
	BOAT-POWER									O	X	XX	XX	X	XX	+
RAFTING	NOVICE										XX	XX	XX	XX	XX	+
	NOV. PREFERR											XX	XX	O	XX	+
	MIDLEVEL												XX	XX	O	+
	LANDING													X	XX	-
CANOEING	NOVICE														XX	+
	MIDLEVEL															+

NOTES: Recreational wading is identical to wade-fishing.
"Hanging-out" is not included since this activity was not investigated using PHABSIM.

KEY:
- 0 no conflict, optima usually within 500 cfs.
- M moderate conflict, optima usually between 500 and 1,000 cfs of each other.
- X extensive conflict, optima between 1,000 and 2,000 cfs apart.
- XX very extensive conflict, optima usually more than 2,000 cfs apart.
- \+ increased flows beneficial.
- \- increased flows detrimental.

Figure 20. Conflict relationships, based on optimum flow requirements, between angling, recreation, and trout life stages for the Chattahoochee River

River between Buford Dam and the confluence with Peachtree Creek were obtained by averaging the values obtained for each of the major reaches. This table is based on the assumption that Morgan Falls Dam will be operated in run-of-the-river mode. The matrix is invalid if Morgan Falls Dam is not operated in this fashion. The matrix also ignores the effects within the pool of the reregulation dam.

131. Examination of Figure 20 provides several pieces of information. First, several activities--midlevel canoeing and rafting (with criteria similar to those for a "white-water" experience) and low-power boat fishing--conflict with all trout life stages and all other activities because they consistently require a flow greater than 4,000 cfs. These activities currently conflict with other uses of the river and, under a revised flow regime, would conflict with other uses. However, these high-flow activities are not currently popular on the river.

132. Representatives of the Georgia Department of Natural Resources indicate that most users who wish a white-water experience travel to other nearby rivers. Also, user profiles indicate that the majority of recreationists utilizing the Chattahoochee River seek what may be best described as a social experience. One exception to the above statement occurs at Powers Landing, where a kayak course is located. Although the flows required in the river to use this course were not assessed, the members of the CRIFS team felt that well over 2,000 cfs would be required.

133. Low-power boat fishing does not appear to be a popular form of angling. The extensive shoal areas that provide the best habitat for trout are difficult to traverse in an outboard-powered boat. Thus, low-power boat fishing is restricted to the nonshoal areas of the river which provide neither the habitat nor the aesthetics that the shoal areas provide. Some fishermen do, however, put in at an access point, then travel to the upper or lower part of a shoal area.

134. Figure 20 also presents the expected effect of increased flows for water supply on each life stage and activity. A minus sign indicates a detrimental effect and a plus sign indicates a beneficial effect. Ignoring the three high-flow activities, the matrix indicates

that higher flows in the river will be beneficial in eight occurrences and detrimental in three. Trout habitat was considered to be improved in all cases because of the elimination of the peaking flows (trout do not have the option of leaving the water, like anglers and recreational users).

135. The trout life stages and remaining activities can be further categorized into those that require primarily lower flows (less than 1,000 cfs) and those requiring moderate flows (1,000 to 2,000 cfs). The life stages and activities in the low-flow category conflict somewhat with the trout life stages and activities in the moderate-flow category. A general categorization of life stages and activities by flow requirement is presented in Table 12.

136. It is important to realize that although the PHABSIM analysis can provide useful information for planning purposes, it does not present a complete description of the relationship between actual recreational use and discharge. First of all, the criteria used for these activities were established through reference to the literature and consultation with experts familiar with the Chattahoochee River. Further study could more accurately estimate the criteria of users. Second, WUA is only a measure of the resource potential for a particular activity; it does not represent user demand for that activity. If the resource is not currently being used to its capacity for that activity, an increase or decrease in WUA may have little or no effect on recreational use. Although total use figures do exist for the Chattahoochee, there is no breakdown on the number participating in the various activities. The distinction between novice-preferred, novice, and midlevel rafting could benefit from further examination. Based on the user motivations described in the introduction, it appears as though many midlevel rafters may actually prefer novice rafting conditions--not for skill considerations, but for social considerations. Additional data are needed to relate actual use patterns and preferences. Finally, the data on users (cited in the introduction) were collected some time ago; it is possible that the characteristics reported have since changed. Even if the data are accurate, they do not include all of the information necessary to address the issues described.

Conflict Resolution

137. An examination of the conflicts identified in the previous section indicates that relatively minor flow manipulations downstream of the site of the proposed reregulation dam may alleviate many of the conflicts among the habitat requirements of the trout life stages, angling, and recreation. Unfortunately, reconciling increased flows for water supply with the activities in the high-flow group will not be possible as a management option. However, this should not be a serious conflict since low-power boat angling and white-water rafting and canoeing are presently not popular uses of the Chattahoochee River. It would seem unreasonable to modify the operation of the river to provide flows for kayaking in the course since a small user group is involved and since such a short length of river is in question. Based on the observations of the CRIFS team, many of the shoal areas at flows between 1,500 and 2,000 cfs will provide adequate river surface area for kayaking (flow requirements for kayaking are very similar to flow requirements for canoeing) with loss only of the marked course and the ease of access and facilities at the present site.

138. The conflicts of the low-flow group of trout life stages and recreational activities versus the moderate-flow group can be resolved in most cases with some flow manipulation either directly at Buford Dam or by a reregulation dam. This manipulation will allow for increased flow in the river for water supply without substantially degrading trout habitat, angling, and recreation. The following paragraphs outline the manner in which these conflicts can be resolved.

139. Brook trout are not stocked in appreciable numbers since, as pointed out earlier, they do not provide a significant return (harvest) for anglers. Rainbow and brown trout are preferentially stocked. Thus, the conflict between water supply and adult brook trout is not significant. Juvenile brown trout habitat for each of the major reaches is optimal at a low flow and appears to conflict with increased flows in the river. However, juvenile trout are stocked primarily downstream of Morgan Falls Dam, which is composed of about 40 percent shoal areas.

The optimum habitat for juvenile brown trout occurs at a higher flow in the shoal areas than in the nonshoal areas (although still slightly lower than the anticipated flow in the river). Thus, stocking of juvenile brown trout only at or near shoal areas will reduce much of the negative impact of increasing flows in the Chattahoochee River. Neither adult brown trout nor adult rainbow trout habitat requirements conflict significantly with increased flows in the river.

140. Conflicts in required flow occur both within and between angling and rafting. However, a separation in time between these activities may eliminate these conflicts. Both wade- and tube-fishing require flows less than the anticipated flow in the river. However, since most angling activity occurs on weekends, it should be possible to reduce flows from either Buford Dam or a reregulation dam over a weekend, specifically for enhanced wade- and tube-fishing.

141. The optimum flow required for nonpower boat angling does not currently occur in the Chattahoochee River. The revised flow in the river would enhance WUA for nonpower boat fishing, as it will fall close to the optimum flow required for this activity. The increased flows in the river for water supply will also enhance low-power boat angling, but will still be substantially below the optimum for this activity. Thus, reduced flows for weekend wade- and tube-fishing and recreation may conflict with boat angling; however, boat angling would be enhanced on weekdays.

142. Much the same recommendation would eliminate conflicts between water supply and rafting. The flow requirements for rafting involve several considerations:

a. Optimum flows for rafting.

b. Optimum flows for raft-landing (for pulling rafts up on shoal areas and riverbanks).

c. Optimum flows for takeout at Paces Mill.

This mix of considerations suggests that the optimum flow for novice rafting and novice canoeing certainly occurs between 750 and 2,000 cfs (about 2,000 cfs strictly for rafting, a maximum of about 1,500 cfs to keep shoal areas exposed, a maximum of 750 cfs for raft-landing on the

shoal areas, and a maximum of about 1,750 cfs for raft takeout at Paces Mill). Probably, a flow between 1,000 and 1,500 cfs would provide the best rafting or canoeing experience. Thus, the proposed weekend reduction in flows from either the reregulation dam or Buford Dam for angling would also enhance novice rafting and canoeing. Further study would be required to more closely define actual user preferences for rafting and canoeing.

143. Table 13 summarizes the effects of the flow recommendations on angling and recreational activities. Trout habitat is not considered since both flow regimes are close to the optima for adult brown trout and adult rainbow trout and certainly more benign than the current peaking flows.

144. The revised flow regime may cause a shift in some recreational uses of the river. The higher flows on the weekdays will cause raft and canoe trips to be shorter and faster; there will be less opportunity for hanging-out since some shoal areas will be more inundated; and raft-landing and takeout may be slightly more difficult. However, some groups may prefer this slightly more exciting experience to the lower flow rafting or canoeing experience.

145. It must be emphasized that the weekend reduced flows recommended for rafting and angling must not cause undue warming of the Chattahoochee River below Morgan Falls Dam, which would jeopardize the trout fishery. Thus, weekend flow requirements for habitat or recreation may be partially determined by water quality considerations.

146. If the reregulation dam is constructed, consideration should be given to operating the reregulation dam to protect boating, angling, and trout habitat within the pool of the reregulation dam. Either the pool of the reregulation dam should be maintained at a level sufficient to prevent dewatering of Bowmans Island Shoals or minimum flows from Buford Dam should be released if the water level in the reregulation dam drops to the point that the boat ramp becomes unusable. This will protect the trout and trout-food organisms from dewatering and stranding and also allow continued use of the reach by boaters and anglers.

PART V: CONCLUSIONS AND RECOMMENDATIONS

147. Increasing flows in the Chattahoochee River to meet the water supply needs of the metropolitan Atlanta area will affect all current uses of the river that are flow related. Some of the effects will be beneficial and some detrimental. However, flow modifications in the channel to provide for water demand can be made that are consistent with all important present uses of the river. The following general recommendations are designed both to provide for increased flow in the river and to optimize as many uses of the river as possible:

a. Release higher flows on weekdays and lower flows on weekends (1,000 cfs or lowest flow that does not result in detrimental water temperatures for trout).

b. Operate Morgan Falls Dam primarily as a run-of-the-river project with some provision for special releases for weekend angling and recreation.

c. Operate Buford Dam, proposed reregulation dam, and Morgan Falls Dam as a system to provide for water supply, recreation, and fish habitat between Morgan Falls and Peachtree Creek.

d. Concentrate stocking of juvenile brown trout to wide shoal areas where optimum habitat occurs at discharges closer to the mean annual discharge than at nonshoal reaches of the river.

e. If a reregulation dam is constructed, consider either maintaining water levels high enough to prevent dewatering of Bowmans Island Shoals, or releasing flows from Buford Dam as the pool within the reregulation dam drops below the level required for use of the boat ramp immediately downstream from Buford Dam. A combination of these two approaches to prevent dewatering of Bowmans Island Shoals may be needed based upon seasonal water quality considerations.

f. Perform studies on the effects of a reregulation dam on downstream water quality.

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Table 1

Representative Cross Sections

Cross Section river mile	Channel Type	Change in Stage, ft, Between 1,000 and 7,500 cfs	Width, ft		Average Depth ft	
			7,500 cfs	1,000 cfs	7,500 cfs	1,000 cfs
346.74	Run	8.0	208	185	11.5	4.4
344.16	Run	5.8	218	206	12.2	6.0
328.62	Run	3.14	268	259	8.1	5.2
328.62	Shoal	3.14	408	390	4.6	1.6
320.72	Run	3.92	234	218	8.7	5.3
319.66	Shoal	2.97	630	590	4.7	1.5
305.55	Shoal	1.7	681	671	3.0	1.4
305.42	Pool	2.4	179	158	11.3	10.2
303.88	Run/bar	5.3	426	289	6.2	1.8

Table 2

Identification of Major Reaches and Subreaches of the Chattahoochee River from Buford Dam to Peachtree Creek

Segment and Reach	River Mile	Type of Cross-Section Data
Buford Dam to site of proposed rereg dam	348.3-342.0	
Bowmans Island Shoals	348.3-347.2	USGS data
Trout hatchery	347.2-342.0	USGS data and field data
Site of proposed rereg dam to headwaters of Bull Sluice Lake	342.0-317.0	
Site of proposed rereg dam to Medlock Bridge	342.0-330.7	Existing USGS data
Medlock Bridge to Jones Bridge	330.7-328.7	Existing CE data
Jones Bridge Shoals	328.7-328.5	Field data
Jones Bridge Shoals to Island Ford Shoals	328.5-320.0	Existing CE data
Island Ford Shoals	320.0-319.0	Field data
Island Ford Shoals to headwaters of Bull Sluice Lake	319.0-317.0	Existing CE data
Below Morgan Falls Dam to Peachtree Creek	312.5-300.5	
Morgan Falls Dam to Devils Race Course Shoals	312.5-305.9	Existing CE data and extrapolated field data
Devils Race Course Shoals	305.9-305.4	Field data
Miscellaneous shoals	305.4-303.8	Existing CE data and extrapolated field data
Paces Mill raft takeout point	303.8	Field data
Paces Mill to Peachtree Creek	303.8-300.5	Existing CE data and extrapolated field data

Table 3

Yearly Trout Stocking Totals for the Chattahoochee River Tailwater Below Buford Dam*

Year	Rainbow Trout	Brook Trout	Brown Trout	Total
1960	7,700	--	4,000	11,700
1961	13,500	--	1,000	14,500
1962	24,500	--	--	24,500
1963	22,580	--	--	22,580
1964	35,960	--	--	35,960
1965	38,279	--	--	38,279
1966	37,890	1,500	--	39,390
1967	41,829	--	4,000	45,829
1968	52,191	--	22,000	74,191
1969	40,612	--	9,000	49,612
1970	82,411	--	4,400	86,811
1971	72,323	26,200	17,000	115,323
1972	82,200	4,000	14,337	100,537
1973	64,200	7,000	40,000	111,200
1974	52,435	4,000	83,300	139,735
1975	69,400	126,600	77,547	273,547
1976	95,381	1,600	54,000	150,981
1977	58,684	24,000	37,928	120,612
1978	67,228	18,268	40,000	125,496
1979	122,787	1,921	6,915	131,623

* Source: Hess 1980.

Table 4

Fish Species Electrofished from the Chattahoochee River, 1977-1979

Taxon	Occurrence* Buford Dam-Morgan Falls	Occurrence* Morgan Falls Dam-Peachtree Creek
Amiidae--bowfins		
Amia calva--bowfin		C
Clupeidae--herrings		
Dorosoma cepedianum--gizzard shad		A
Esocidae--pikes		
Esox niger--chain pickerel	R	R
Cyprinidae--minnows and carps		
Cyprinus carpio--carp	C	A
Ericymba buccata--silverjaw minnow		R
Nocomis leptocephalus--bluehead chub	R	
Notemigonus crysoleucas--golden shiner	R	
Catostomidae--suckers		
Carpoides cyprinus--quillback		A
Catostomus commersoni--white sucker		C
Erimyzon oblongus--creek chubsucker	R	R
Hypentelium etowanum--Alabama hogsucker	R	C
Ictiobus sp.--unidentified buffalo		R
Minytrema melanops--spotted sucker	R	R
Moxostoma lachneri--greater jumprock	R	R
Moxostoma poecilurum--greyfin redhorse	C	A
Ictaluridae--freshwater catfishes		
Ictalurus brunneus--snail bullhead		R
Ictalurus melas--black bullhead		C
Ictalurus natalis--yellow bullhead		R
Ictalurus nebulosis--brown bullhead	R	A
Ictalurus punctatus--channel catfish	R	
Centrarchidae--sunfishes		
Lepomis auritus--redbreast sunfish	R	A
Lepomis cynellus--green sunfish	C	C
Lepomis gulosus--warmouth	R	

(Continued)

Notes: C = common (0.5 to 2.5 fish per hour), A = abundant (>2.5 fish per hour of electrofishing), R = rare (<0.5 fish per hour).

* Source: Hess 1980.

Table 4 (Concluded)

Taxon	Occurrence: Buford Dam-Morgan Falls	Occurrence: Morgan Falls Dam-Peachtree Creek
Centrarchidae--sunfishes (Continued)		
Lepomis macrochirus--bluegill	A	A
Lepomis microlophus--redear sunfish	R	R
Micropterus punctulatus--spotted bass	R	R
Micropterus salmoides--largemouth bass	C	C
Micropterus sp., cf. *coosae*--shoal bass		R
Pomoxis nigromaculatus--black crappie	C	A
Percidae--perches		
Perca flavescens--yellow perch	A	A
Percina nigrofasciata--blackbanded darter		R
Cottidae--sculpins		
Cottus carolinae--banded sculpin	R	R
Cottus sp., cf. *bairdi*		R

Table 5

Demographic and Group Characteristics of Chattahoochee River Users*

Characteristics	Little (1982) Study	MacDonald and Hammitt (1979) Study
Age	28**	28†
Married, percent	40	††
White, percent	93	††
With college education, percent	47	55
Percent in groups of five or less, percent	70‡	63
Social group, percent		
Alone	8	0
Family	24	16
Friends	37	54

* Little (1982) included all park users; MacDonald and Hammitt (1979) included only rafters and other floaters.
** Median.
† Mean.
†† Not collected in the survey.
‡ Group of one to four people.

Table 6

Trip Characteristics

Characteristic	Percentage of Respondents
Length of stay	
0-2.0 hr	17.8
2.1-4.0 hr	37.7
4.1-6.0 hr	31.8
6.1+ hr	8.9
Frequency of visits	
No more than a few times per year	34.1
At least once a month	40.0
At least once a week	23.7

* Source: Little (1982).

Table 7

Agencies Involved in the Chattahoochee River Instream Flow Study*

Agency	Contribution
Georgia Game and Fish Division	Identified issues, developed fishery and recreation criteria, assisted in fieldwork
Georgia Environmental Protection Division	Developed recreation criteria
US Fish and Wildlife Service	All aspects of study
US Geological Survey	Collected field data
US National Park Service	Identified issues, assisted in development of recreation criteria
US Army Engineer Waterways Experiment Station	All aspects of study
US Army Engineer District, Savannah	Managed study
Atlanta Regional Commission	Coordination
US Environmental Protection Agency	Coordination

* Participation by an agency does not imply endorsement of either the study results or conclusions.

Table 8

Channel Index for Trout, Developed Specifically for the Chattahoochee River

Channel Index	Suitability	Description
1.0	0.10	All sand--no cover
1.5	0.15	Gravel--no cover
2.5	0.25	Sand--some cover
3.0	0.30	Sand--extensive cover
4.0	0.40	Gravel--extensive cover
5.0	0.50	Cobble (75-254 mm)--some cover
6.0	0.60	Boulder (>254 mm)--some cover
7.0	0.70	Bedrock--some cover
8.0	0.80	Cobble--extensive cover
9.0	0.90	Bedrock--extensive cover
10.0	1.00	Boulder--extensive cover
11.0	0.50	Upland vegetation

Table 9

Recreation Activities for Which Suitability Criteria Were Obtained, Modified, or Generated

Activity	Definition
Canoeing	
Novice (river) Novice (shoal)	Depths and velocities preferred by inexperienced canoeists. Depth must be less than 4 ft to allow canoeist to right a turned-over canoe.
Midlevel	Depths and velocities preferred by experienced canoeists.
Rafting	
Novice	Depths and velocities preferred by inexperienced slow-water rafters.
Novice (preferred)	Same criteria as for novice rafters except that depths and velocities are reduced for safety.
Midlevel	Depths and velocities preferred by experienced rafters.
Landing	Depths and velocities preferred to successfully land a raft.
Fishing	
Wading	Depths and velocities required for wade-fishing.
Tubing	Depths and velocities required for tube-fishing.
Boating (nonpower) Boating (low-power)	Depths and velocities preferred for boat fishing with and without small outboard engines.

Table 10

Water Surface Elevations (feet)* at Three Discharge Levels for Cross Sections in the Major Shoal Areas and Paces Mill

Location	Discharge, cfs		
	1,000	1,500	2,000
Jones Bridge Shoals (river mile 328.6)	23.66	24.15	24.54
Island Ford Shoals (river mile 319.7)	29.77	30.28	30.66
Devils Race Course Shoals (river mile 305.9)	10.16	10.74	11.21
Paces Mill (river mile 303.9)	12.04	12.58	13.08

Note: Water surface elevations are based on an arbitrary datum for each reach.

Table 11

Relative Travel Time in the Chattahoochee River Downstream of Buford Dam and Upstream of Peachtree Creek*

Discharge** cfs	Upstream of State Road 20 Bridge	State Road 20 to Medlock Bridge	Medlock Bridge to Bull Sluice Landing	Morgan Falls to Powers Island	Powers Island to Paces Mill	Morgan Falls to Peachtree Creek
500	1.59	1.50	1.53	1.35	1.49	1.40
750	1.22	1.16	1.21	1.13	1.17	1.14
1,000	1.00	1.00	1.00	1.00	1.00	1.00
1,250	0.86	0.89	0.86	0.90	0.88	0.89
1,500	0.76	0.82	0.76	0.83	0.79	0.82
1,750	0.70	0.76	0.69	0.78	0.72	0.76
2,000	0.64	0.71	0.63	0.73	0.67	0.71
2,500	0.56	0.64	0.55	0.66	0.58	0.64
3,500	0.46	0.54	0.44	0.57	0.48	0.54
5,000	0.39	0.46	0.35	0.48	0.38	0.45
7,500	0.33	0.38	0.28	0.41	0.29	0.37
12,000	0.28	0.32	0.23	0.34	0.21	0.30

* Bull Sluice Landing and Powers Island are located at river miles 312.3 and 306.5, respectively. Locations of other reference sites are shown in Figures 1-3.

** Reference discharge is 1,000 cfs.

Table 12

Categorization of Trout Life Stage, Angling, and Recreation by Flow Requirements

Flow Requirement	Activity of Life Stage
Low (<1,000 cfs)	Juvenile brown trout Adult brook trout Wade-fishing Tube-fishing Raft-landing Wading
Moderate (1,000-2,000 cfs)	Adult brown trout Adult rainbow trout Nonpower boat fishing Novice rafting Novice (preferred) rafting Novice canoeing
High (>2,000 cfs)	Low-power boat fishing Midlevel rafting Midlevel canoeing

Table 13

Effects of Flow Recommendations to Minimize Conflicts Between Beneficial Uses of the Chattahoochee River

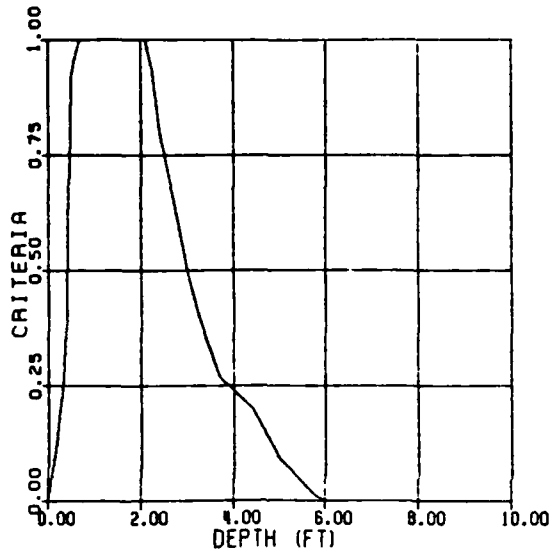
Activity	Weekday Flow (>1,500-2,000 cfs)	Weekend Flow (>1,000-1,500 cfs)*
Wade-fishing	Possible	Optimum
Tube-fishing	Possible	Optimum
Nonpower boat fishing	Optimum	Possible
Novice rafting	Possible	Optimum
Novice canoeing	Possible	Optimum
Hanging-out	Possible	Optimum
Wading	Possible	Optimum

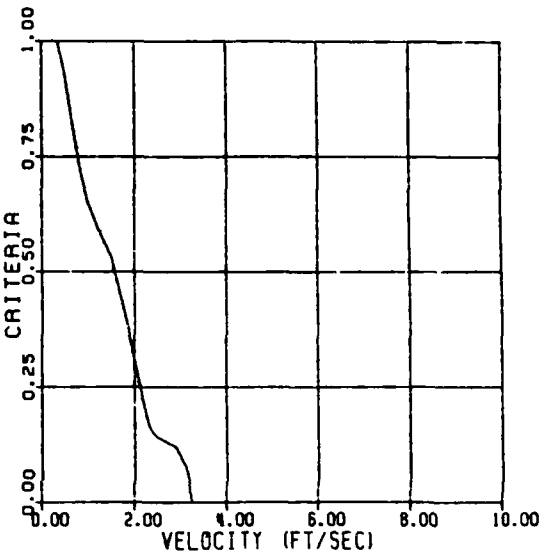
* Lowest summertime flow to be determined by water temperature considerations.

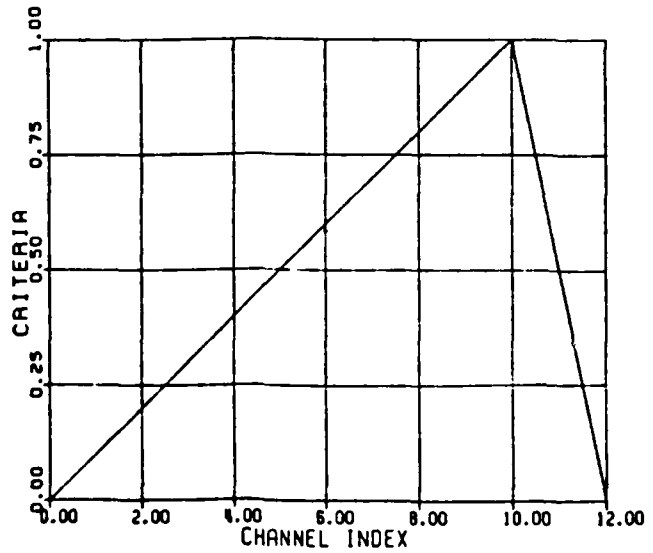
APPENDIX A: SUITABILITY CURVES FOR TROUT SPECIES

BROWN TROUT--JUVENILE

11501 29-AUG-84

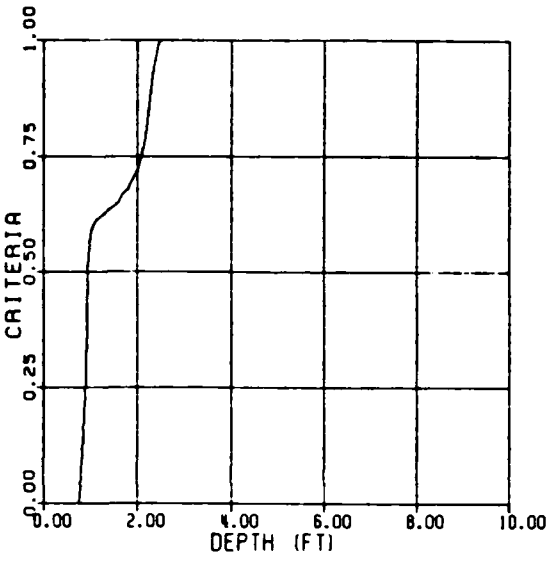


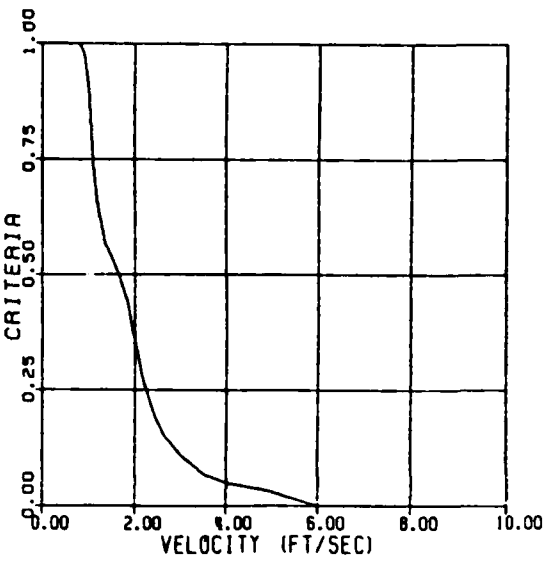


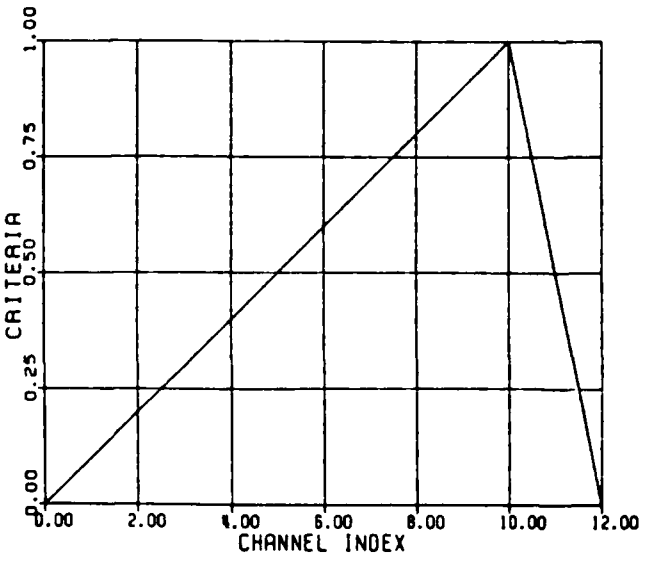


BROWN TROUT--ADULT

11302 29-AUG-84

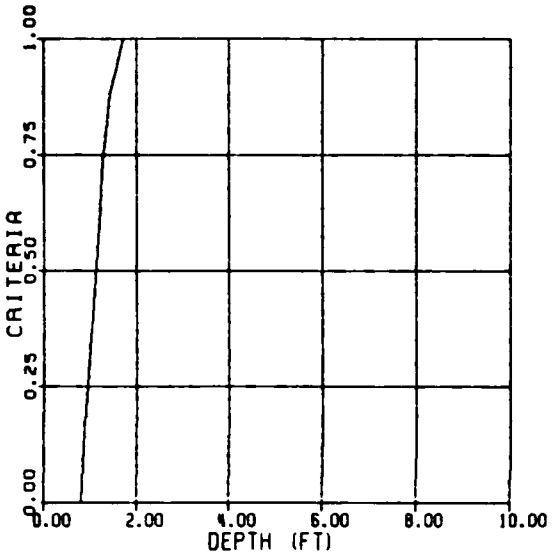


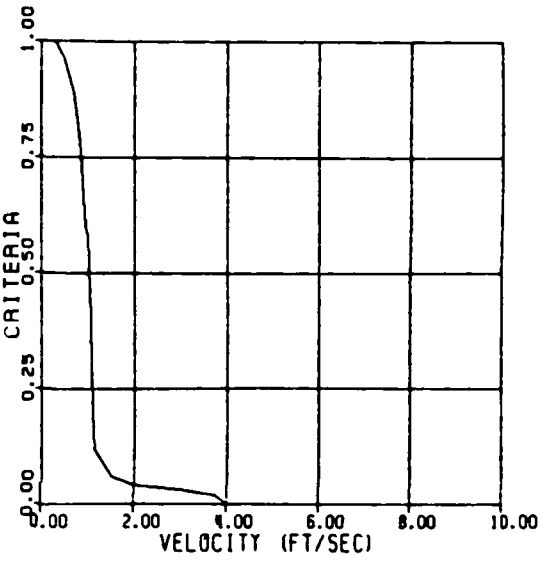


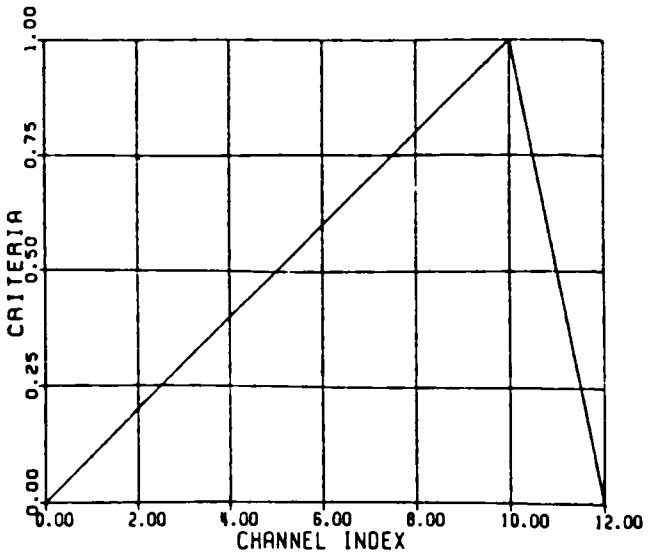


BROOK TROUT (SHOAL)--ADULT

11402 29-AUG-84

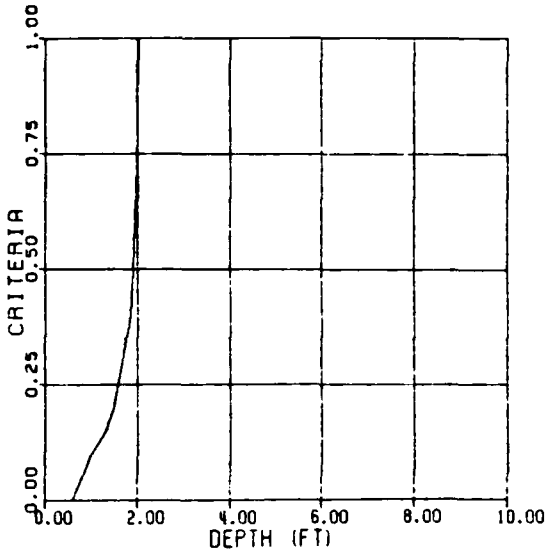


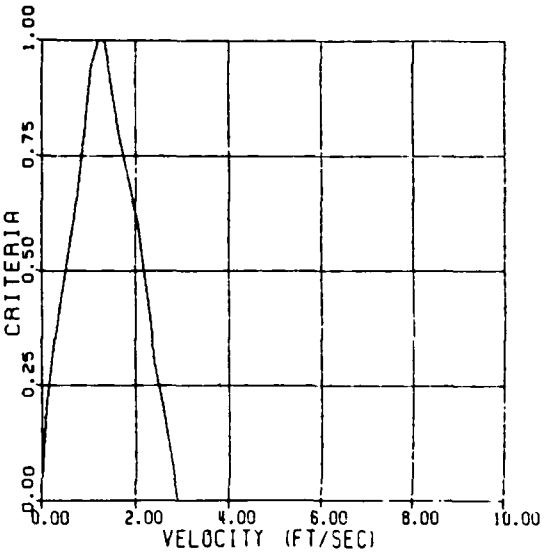


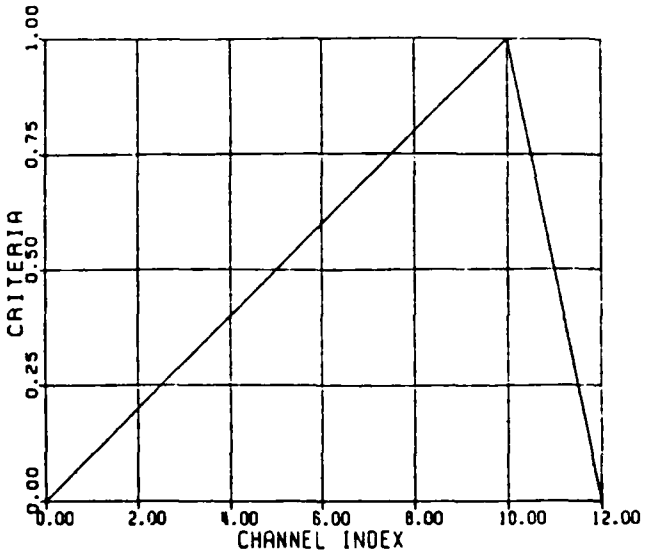


RAINBOW TROUT--ADULT

11102 29-AUG-84



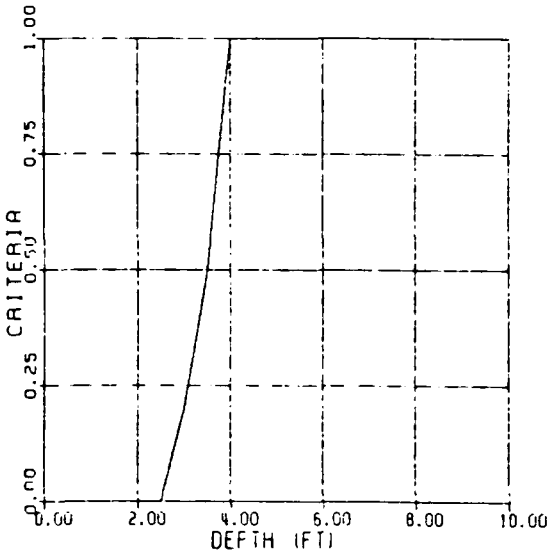


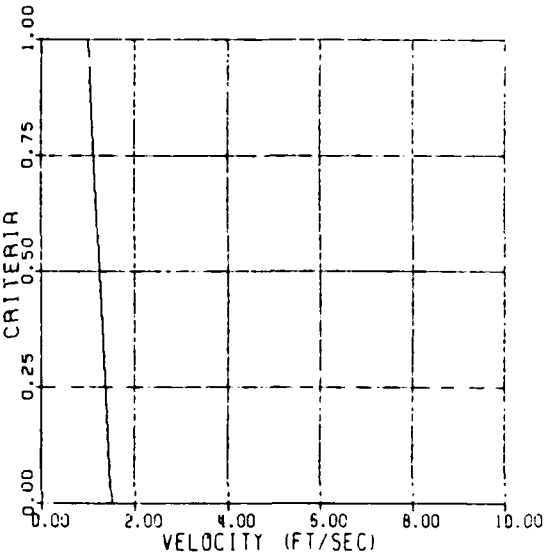


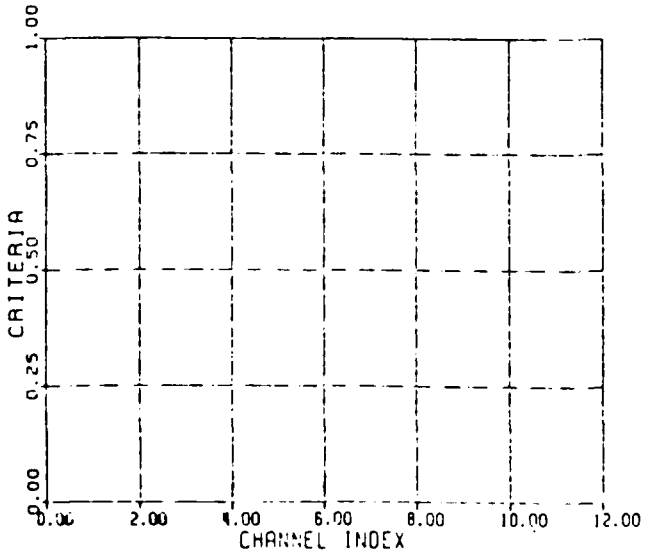
APPENDIX B: SUITABILITY CURVES FOR RECREATIONAL FISHING ACTIVITIES

SUITABILITY OF USE CRITERIA-FISHING/TUBI

70010 20-AUG-84

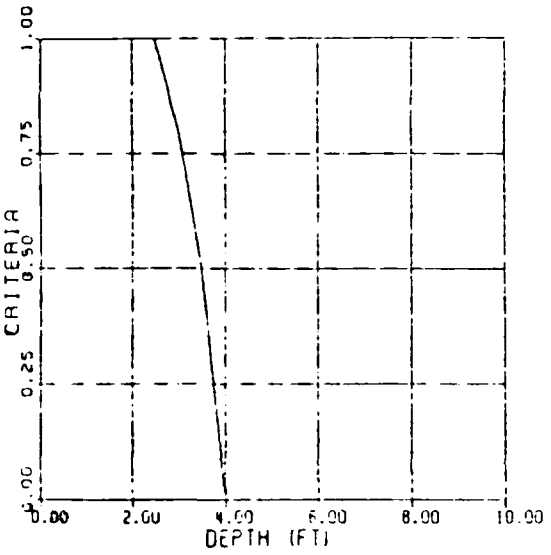


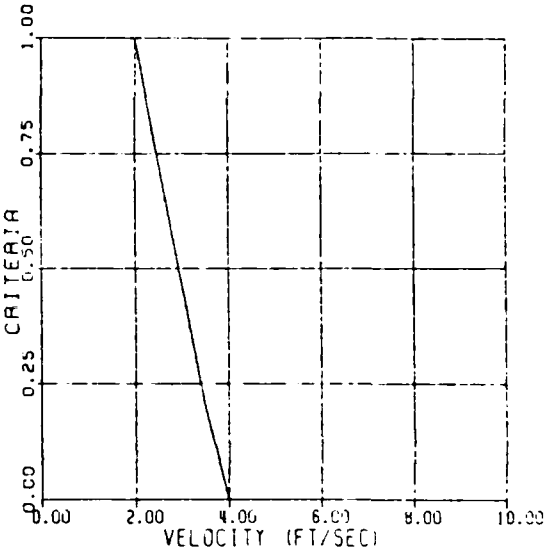


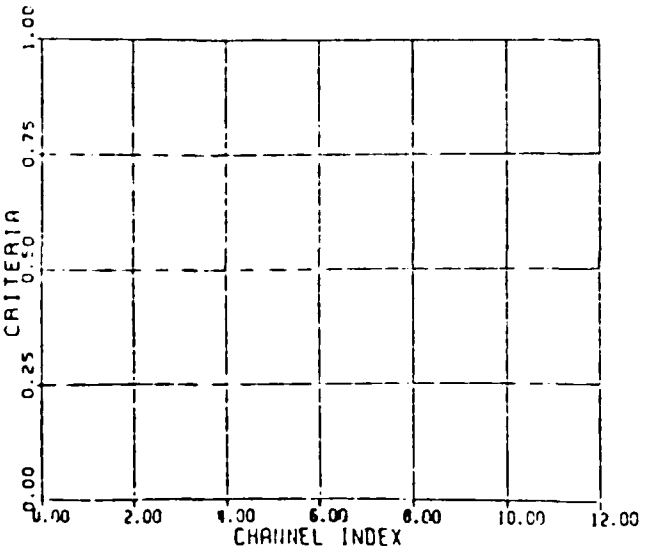


SUITABILITY OF USE CRITERIA- FISHING/WAD

70000 20-AUG-84







AD-A172 725 ENVIRONMENTAL AND WATER QUALITY OPERATIONAL STUDIES 2/2
EFFECTS OF FLOW ALTRR (U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS ENVIR
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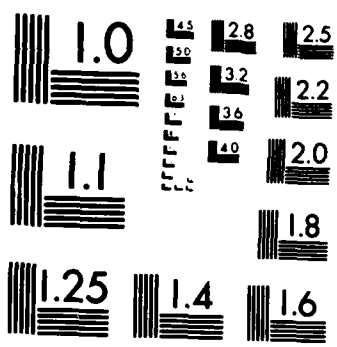

FISHING (FROM INFO PAPER NO. 6)/BOAT-NFR

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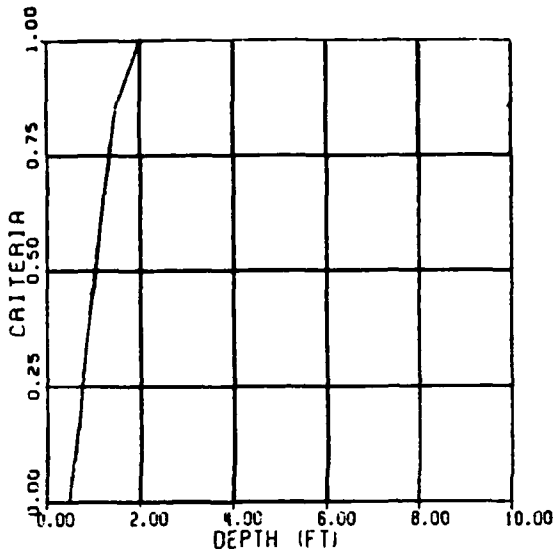

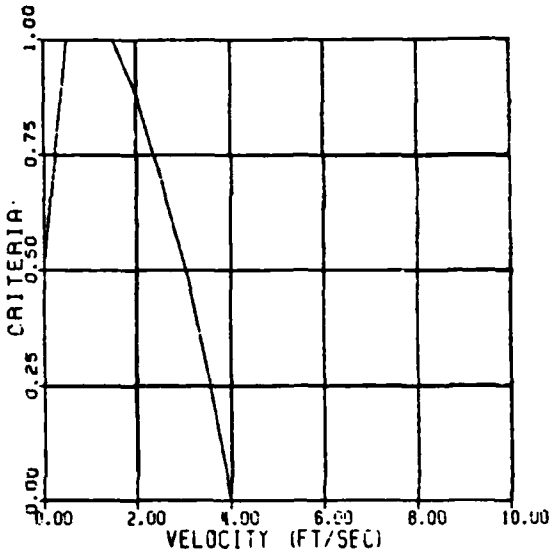

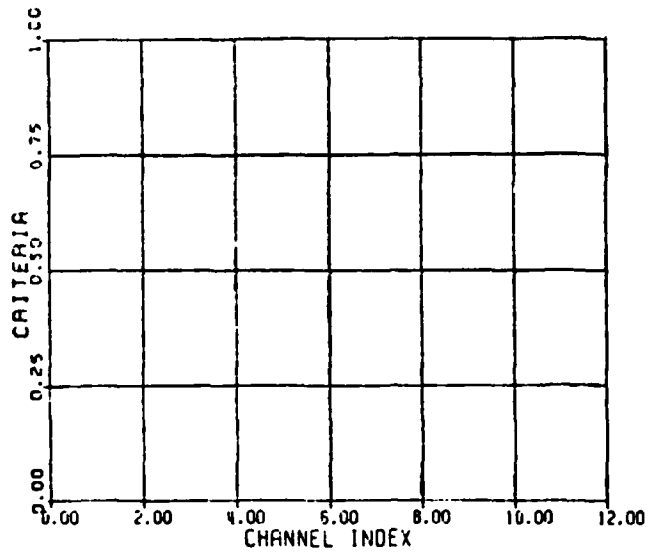

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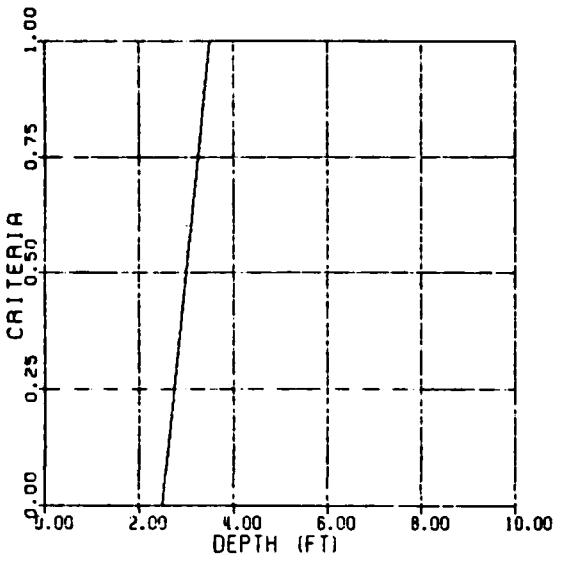
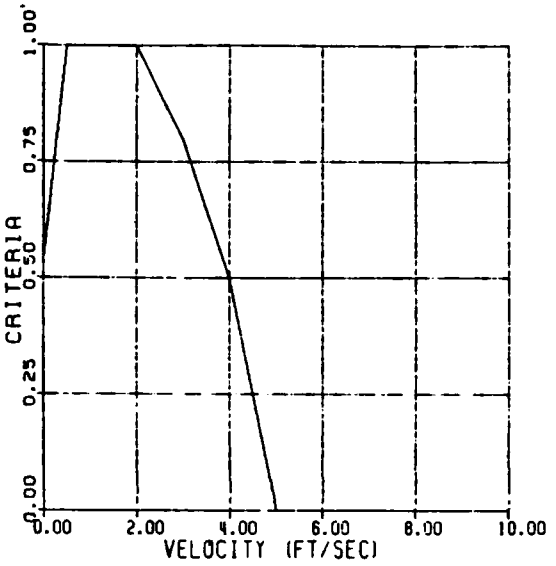
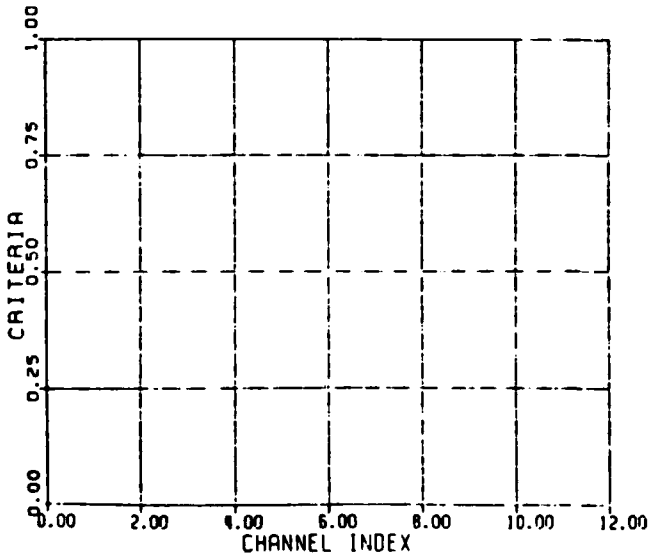


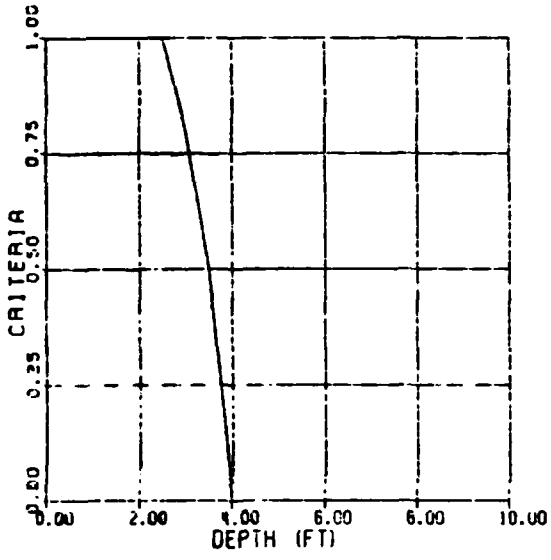


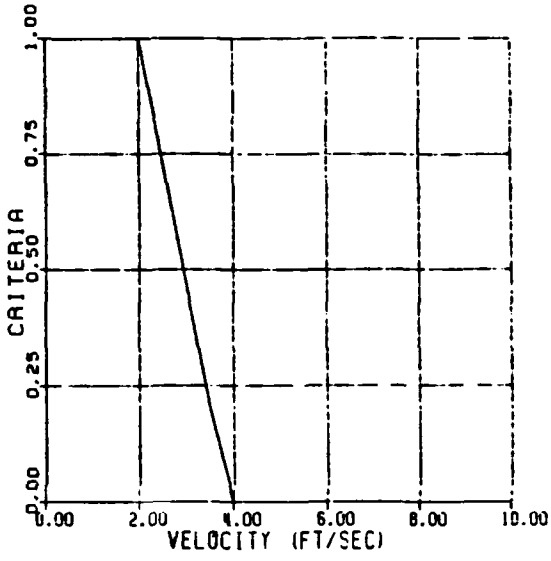


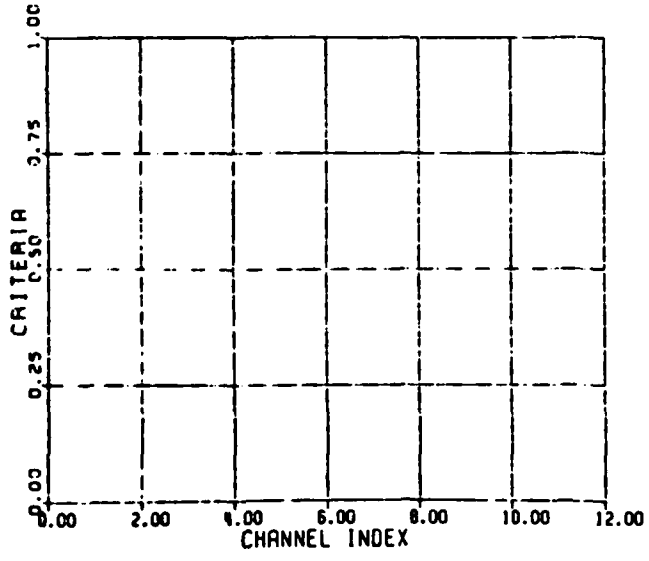
APPENDIX C: SUITABILITY CURVES FOR RECREATIONAL ACTIVITIES

SUITABILITY OF USE CRITERIA-WC/WADING

71010 20-AUG-84

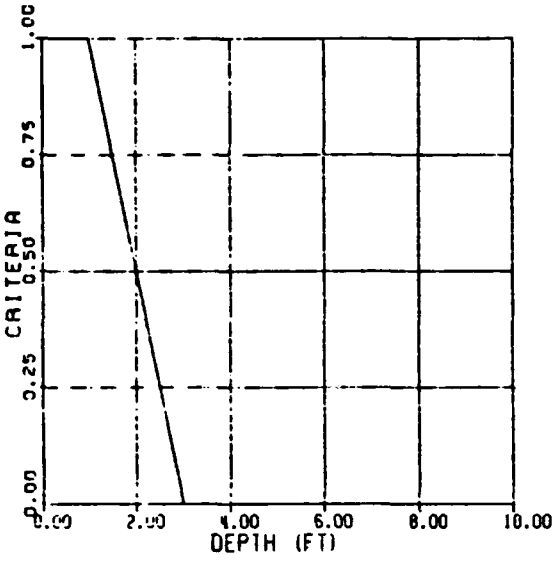


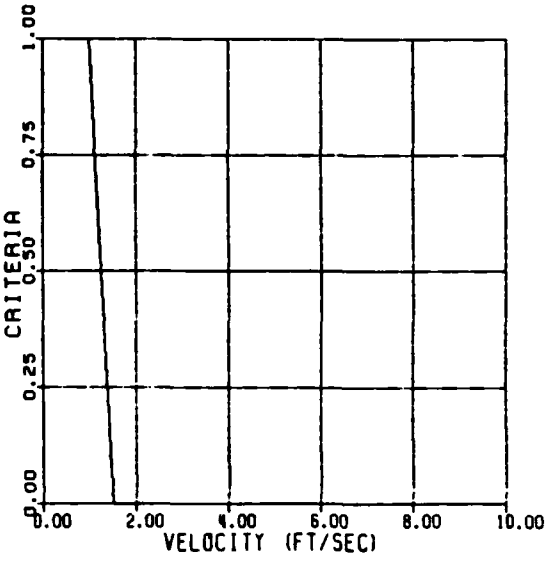


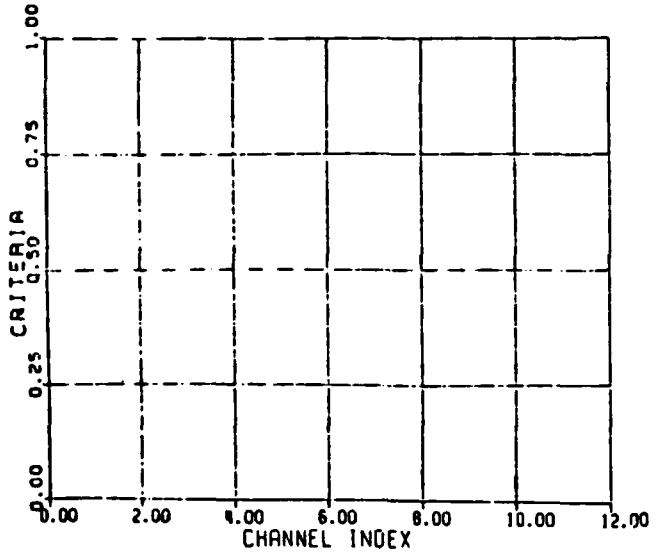


SUITABILITY OF USE CRITERIA-RAFT/LANDING

720400 20-AUG-84

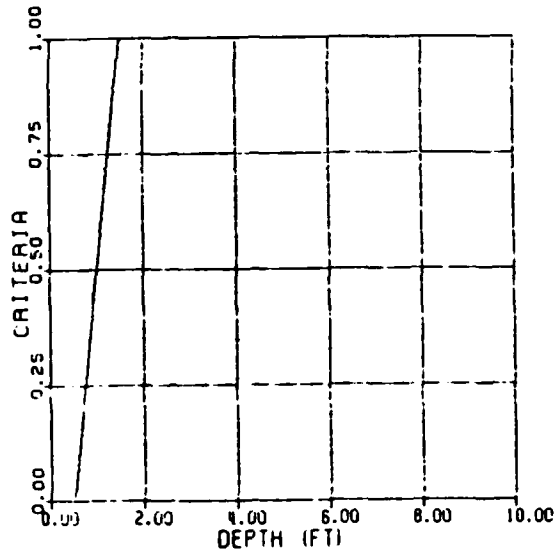


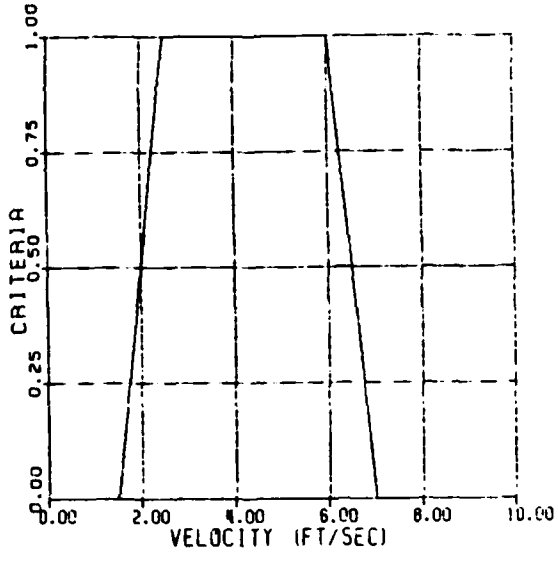


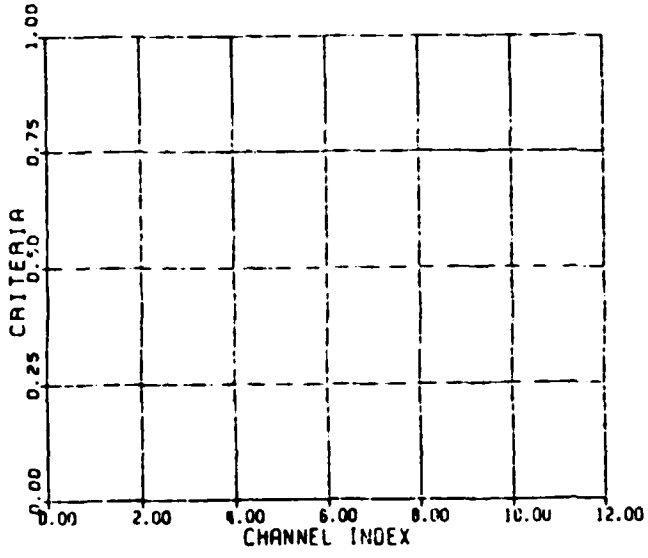


SUITABILITY OF USE CRITERIA-CANOE/MID-LE

720303 20-AUG-84







SUITABILITY OF USE CRITERIA-RAFT/NOVICE

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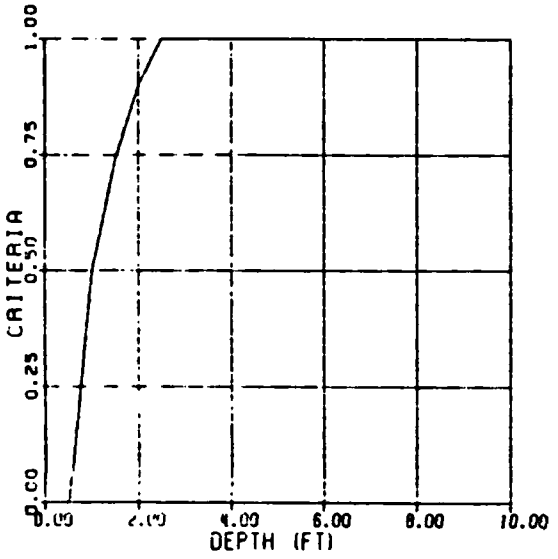
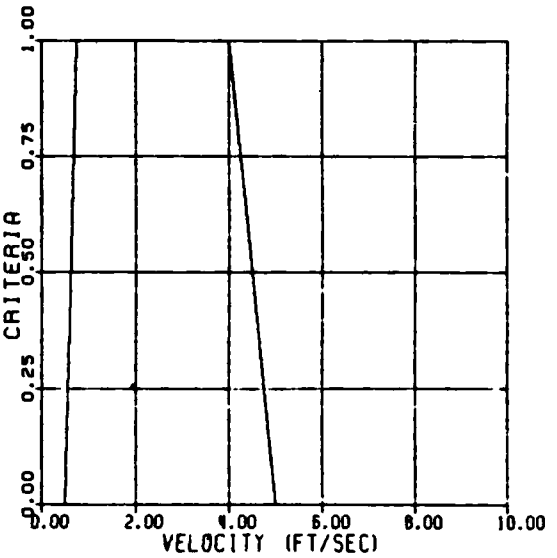
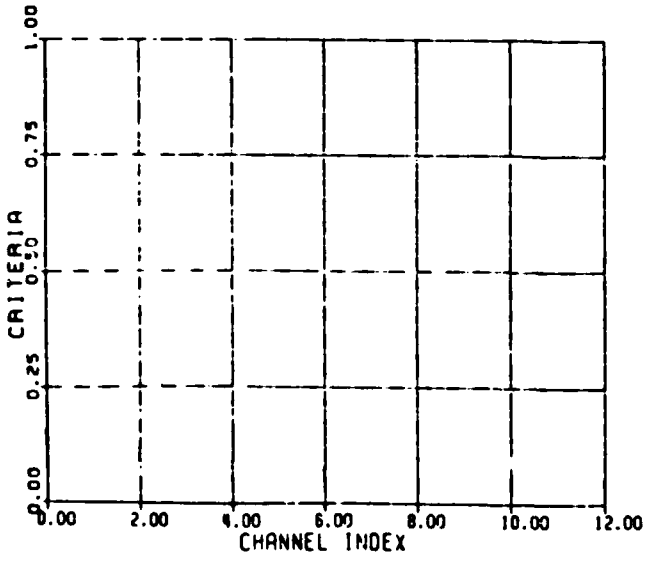
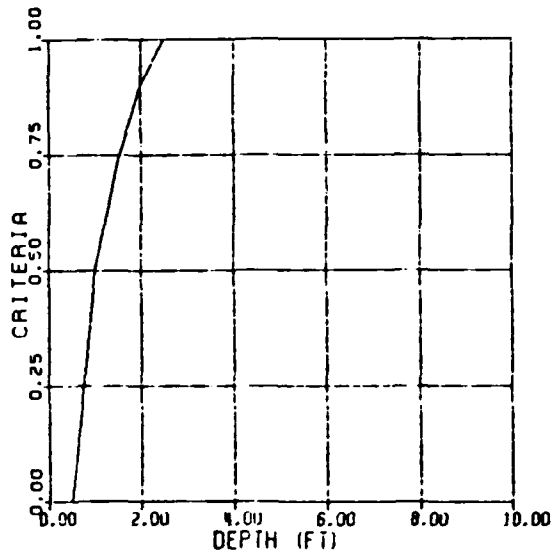


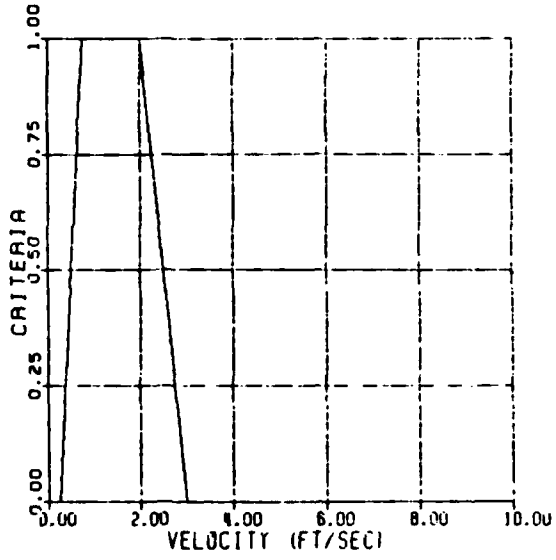


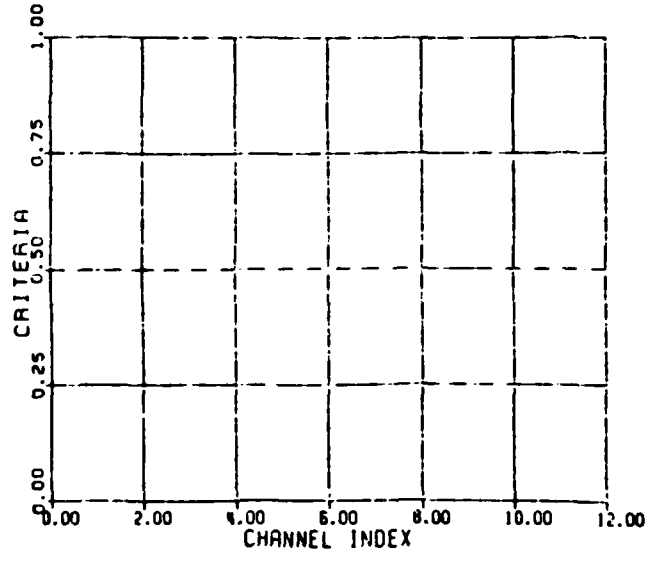


SUITABILITY OF USE CRITERIA-RAFT/NOV-P

720402 20-AUG-84







SUITABILITY OF USE CRITERIA-RAFT/MID-LEV

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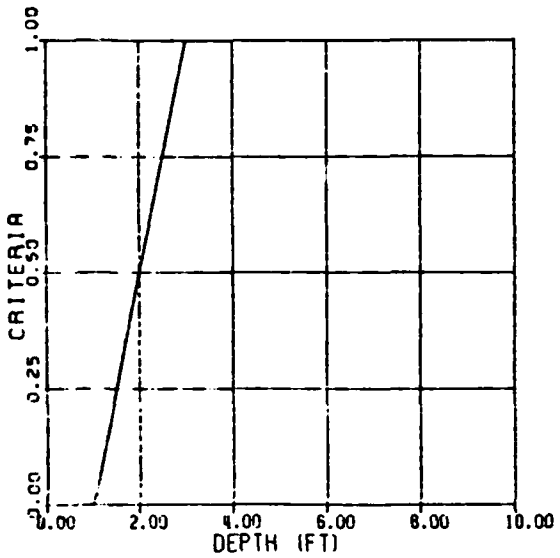

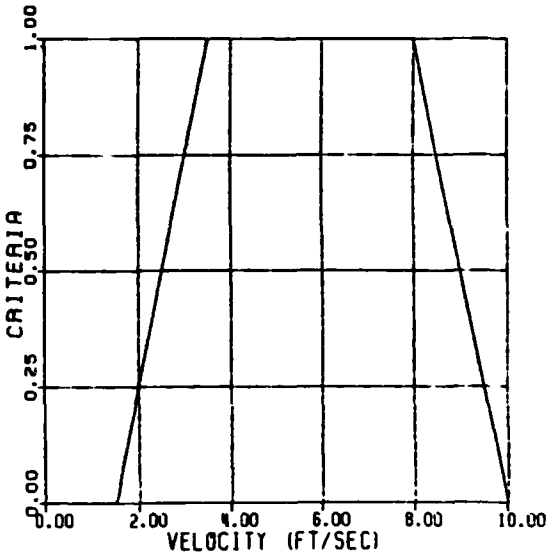

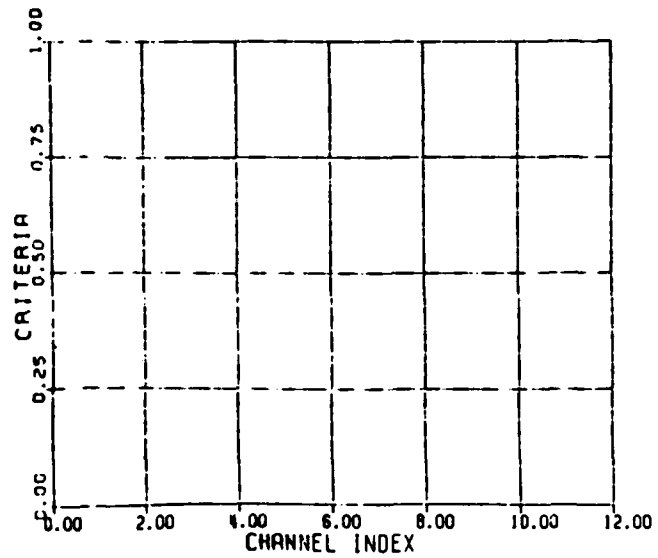

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